.

Altitude Combustion Stand Independent Review

Volume II: Appendices

November 10, 2010

Volume II: Appendices

Appendix A. Identification of White Sands Test Facility (WSTF) Technical Capability Forward Plan Operations, dated July 16, 2002

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

July 16, 2009

Reply to Attn of:

Space Operations Mission Directorate

TO: Manager, Rocket Propulsion Test Program

FROM: Associate Administrator for Space Operations
Associate Administrator for Exploration Systems

SUBJECT: Identification of White Sands Test Facility (WSTF) Technical Capability Forward Plan Options

Information presented at the April 7, 2009, Human Space Flight Capability Forum-3 and the May 5, 2009, Joint Resources Review indicates appreciable differences between the annual funding from NASA Programs at the White Sands Testing Facility (WSTF) and an extrapolation of WSTF fiscal year (FY) cost after FY 2010. It is important to identify for the Agency an executable forward plan that will reduce these annual differences to magnitudes which may be eventually reconciled with reasonable amounts of reimbursable business. The WSTF Design Development Test and Evaluation and Operations (DDT&E/Ops) capability cost is currently approximately $37 million per year. Beginning in FY 2011, the disconnect of cost to continue the capabilities at current levels compared to budgeted program resources for WSTF activities ranges from $19 million-$25 million per year.

The WSTF of the Johnson Space Center (JSC) supports two major human spaceflight functions:

1. The advancement, development, design, integration, test and evaluation of:

   a. Human-rated spacecraft propulsion systems, particularly deep space engines;
   b. Hypervelocity impact hazards and protection systems for orbital and micrometeoroid debris protections;
   c. Oxygen system safe design, hazard and failure analysis and testing, and
   d. Hazardous and energetic fluid systems safe design and materials compatibility testing.

2. The planning, analysis, preparation, certification and execution of human space missions:

   a. Repair and refurbishment of reusable propulsion and life support hardware.

b. Space Shuttle practice approaches and landings and contingency landing facility operation for Space Shuttle missions. (Note: there is no requirement for this capability after the last Space Shuttle mission.)

The team will conduct an assessment of each technical capability (1a-d and 2a) of the WSTF to identify options for forward plans that will correctly size the WSTF capability for the work levels expected in the years after the last Space Shuttle mission. This assessment should cover all WSTF capabilities, not just rocket propulsion testing. Please take into account the most recent plans of the Constellation Program and other NASA program DDT&E requirements, schedules and utilization plans for WSTF in formulating the recommended executable plan. This effort should primarily use and update available information and collect new data only as necessary to complete this assessment and develop executable forward plans for WSTF. This existing information includes the Constellation PMR-09 schedules, the Exploration Requirements for Institutional Capabilities Study, and the NASA Facilities Study, "WSTF Capability Review and Studies on WSTF Technical Capabilities", and other studies sponsored by the Transition Control Board and the Technical Capabilities Working Group.

The assessment shall include a description of the existing WSTF capabilities, a review of future NASA program/project requirements for the facility's capabilities over the 2011-2015 budget horizons, and a recommendation for sizing and funding each capability and the overall WSTF to meet the known NASA requirements. Please focus particularly on those periods of time when NASA utilization is expected to be low compared to the Space Shuttle era level of utilization. If specific technical capabilities exist at WSTF and also other NASA sites, please recommend any specific closure, consolidations or relocations to or from WSTF, along with transfer cost and expected savings to lower overall NASA annual cost for such capabilities. Identify unique environmental considerations that influence the decision making process. Also provide recommendations/projections on type and quantity of reimbursable sustainment work, and projection of total annual WSTF resources that could be used as the basis for future Exploration Systems Mission Directorate (ESMD) and Space Operations Mission Directorate Planning, Programming, Budgeting and Execution (PPB&E) guidance. The final product will be in the form of an executable plan with projected cost/savings, schedule and appropriate options to sustain a right-sized WSTF in the post Shuttle era.

Although the bulk of this effort will fall on the assessment team, JSC and the WSTF staff, we ask all relevant mission directorates, programs and projects to fully support your assessment as you require. Please deliver the final executable forward plan for WSTF no later than August 31, 2009.

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If you have questions or comments on this direction, please contact Mr. Joel Kearns at (202) 358-1223, or Mr. Robert Soltess at (202) 358-1895.

Sincerely,

William H. Gerstenmaier

Douglas R. Cooke

Appendix B. White Sands Test Facility "Right Size" - Phase 1, Dated September 3, 2009

Topics

- Task
- Study Approach
- Options Reviewed
- Bottom Line Up-Front
- Yet to be done – Phase II
- Previous Studies
- Review
  - » WSTF Budget Overview
  - » WSTF Core Capabilities
  - » Integrated Schedule
  - » General Assumptions
- Propulsion Core Capability
- Laboratories Core Capability
- Hardware Processing Core Capability
- Center Maintenance and Operations
- Available For New Work
- Summary
- Recommendations

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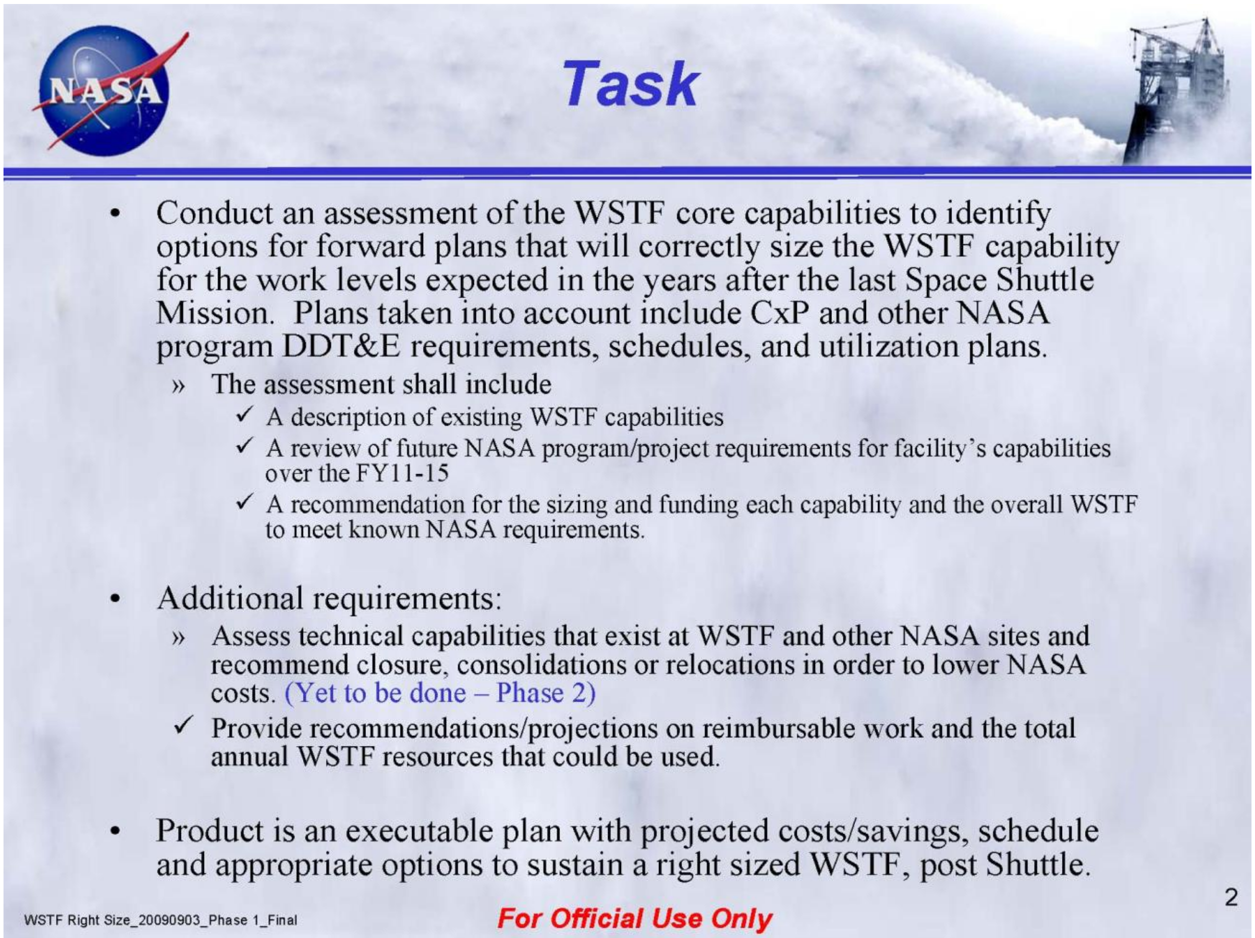
Task
• Conduct an assessment of the WSTF core capabilities to identify options for forward plans that will correctly size the WSTF capability for the work levels expected in the years after the last Space Shuttle Mission. Plans taken into account include CxP and other NASA program DDT&E requirements, schedules, and utilization plans.
» The assessment shall include
✓ A description of existing WSTF capabilities
✓ A review of future NASA program/project requirements for facility's capabilities over the FY11-15
✓ A recommendation for the sizing and funding each capability and the overall WSTF to meet known NASA requirements.
• Additional requirements:
» Assess technical capabilities that exist at WSTF and other NASA sites and recommend closure, consolidations or relocations in order to lower NASA costs. (Yet to be done – Phase 2)
✓ Provide recommendations/projections on reimbursable work and the total annual WSTF resources that could be used.
• Product is an executable plan with projected costs/savings, schedule and appropriate options to sustain a right sized WSTF, post Shuttle.
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Study Approach
• Defined Gap
• Defined Functional Areas
• Requirements Alignment to Core Capabilities
• Reviewed Previous Studies
• Developed Options
• Performed Analysis
• Recommendation
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Options Reviewed

- Propulsion
  - » Right Size #1
    - ➢ Facility "state" based on maintaining core capabilities, present test commitments, and highly anticipated test programs.
      - – Includes committed work as of 8/31/09
      - – Includes anticipated projects based on RPT planning references, Constellation TIG planning references, and 2006 Bottoms Up Review (BUR)
  - » Right Size #1a- Mothball 300 area
    - ➢ Facility "state" based on present testing commitments, highly anticipated test programs, and maintaining core capabilities, but with directed mothball of the entire 300 area.
    - ➢ Includes removal of stored propellants from 300 area and transport off site to an undetermined location.
  - » Right Size #2- Meeting Current Commitments
    - ➢ Facility "state" based on present test commitments and maintaining core capabilities
  - » Right Size #3- Maintaining Core
    - ➢ Facility state based on minimum site support required to maintain core competency with no test customers
    - ➢ Assumed to start in FY10
  - » Right Size #4 – Similar to Right Size #2, Meeting Current Commitments
    - ➢ Portion of the Maintenance and Core test WYE's are shared (30% of Core WYE's will perform maintenance
- Laboratories – the minimum ability to maintain the technical test capability and test facility infrastructure necessary to meet the already negotiated and reasonably assured testing requirements from NASA programs
- Hardware Processing – the minimum ability to maintain the technical capabilities and infrastructure necessary to meet the needs of the Propulsion and Laboratories functional areas
- CMO – Reductions in dependent requirements founded in the 4 different Propulsion options and the minimum Laboratories and Hardware Processing states

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Bottom Line Up-Front

$M	FY09	FY10	FY11	FY12	FY13	FY14	FY15	10-15 Total
March 2008 HSCF II Gap	$10,700.0	$0.0	$24,200.0	$29,700.0	$29,700.0	$33,000.0		$116,600.0
April 2009 HSCF III Gap	$0.0	$2,600.0	$14,900.0	$23,200.0	$27,600.0	$31,200.0	$32,300.0	$131,800.0
HSCF Includes 2.8% Inflation per year								
Right Size Totals		$50,134.0	$45,459.0	$46,829.0	$48,697.0	$50,113.0	$51,391.0	$292,623.0
Right Size Assessment Includes 3.0% Inflation per year								
Total Available Funding		$39,311.0	$32,159.0	$30,377.0	$30,372.0	$30,402.0	$30,677.0	$193,298.0
Right Size Gap without assessments		$10,823.0	$13,300.0	$16,452.0	$18,325.0	$19,711.0	$20,714.0	$99,325.0
Program Assessments		$6,010.0	$1,691.0	$1,377.0	$1,377.0	$1,377.0	$1,377.0	$13,209.0
Right Size Gap with assessments		$4,813.0	$11,609.0	$15,075.0	$16,948.0	$18,334.0	$19,337.0	$86,116.0
Available For New Work		$0.0	$1,459.0	$2,077.0	$3,068.0	$3,434.0	$3,550.0	$13,588.0
Total Gap		$4,813.0	$13,068.0	$17,152.0	$20,016.0	$21,768.0	$22,887.0	$99,704.0
Delta Between HSCF III and Right Size		$2,213.0	$1,832.0	$6,048.0	$7,584.0	$9,432.0	$9,413.0	$32,096.0

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Core Capabilities Budget Summary

FY	Propulsion		Laboratories		Hardware Processing		CMO		Total	
	Total Cost delta budget	WYE	Total Cost delta budget	WYE	Total Cost delta budget	WYE	Total Cost delta budget	WYE	Total Cost delta budget	WYE
FY10	$4,554 $210	36	$9,943 $692	70	$6,398 $183	61	$29,239 ($11,908)	187	$49,864 ($10,553)	354
FY11	$4,774 ($56)	37	$8,372 ($1,729)	71	$5,184 ($1,655)	43	$27,129 ($9,860)	181	$45,318 ($13,159)	332
FY12	$5,632 ($860)	43	$8,374 ($2,920)	61	$5,339 ($2,519)	43	$27,484 ($10,153)	171	$46,684 ($16,307)	318
FY13	$6,247 ($1,825)	47	$8,644 ($2,987)	61	$5,498 ($2,844)	43	$28,308 ($10,669)	171	$48,547 ($18,175)	322
FY14	$6,651 ($2,229)	49	$8,744 ($3,189)	60	$5,663 ($3,145)	43	$29,055 ($11,148)	171	$49,959 ($19,557)	323
FY15	$6,802 ($2,380)	49	$8,909 ($3,337)	59	$5,834 ($3,371)	43	$29,846 ($11,626)	171	$51,232 ($20,555)	322
6 Yr Total	$34,660 ($7,140)		$52,986 ($13,469)		$33,916 ($13,351)		$171,061 ($65,364)		$292,623 ($99,325)	

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M - $4M per yr.

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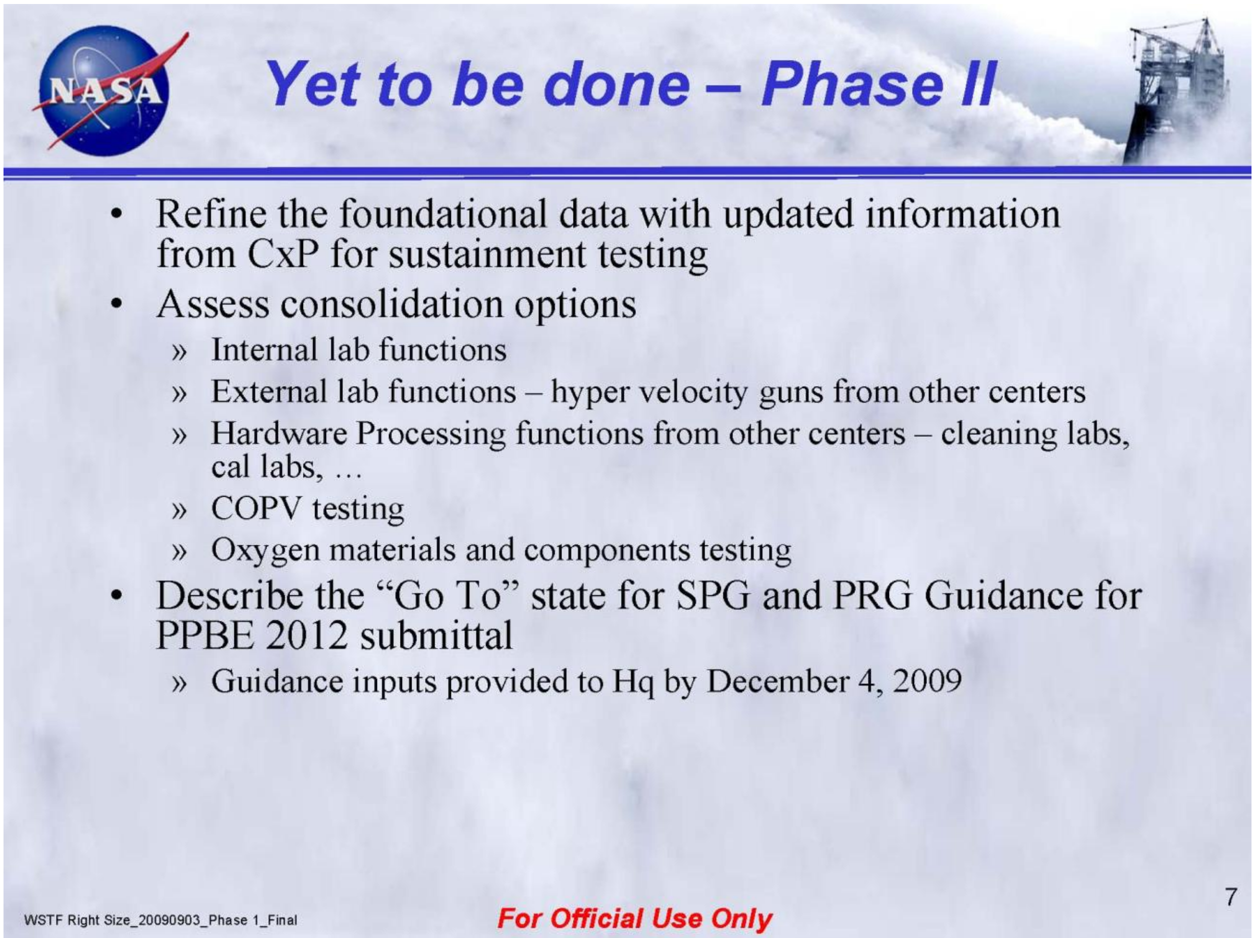

Yet to be done – Phase II
• Refine the foundational data with updated information from CxP for sustainment testing
• Assess consolidation options
» Internal lab functions
» External lab functions – hyper velocity guns from other centers
» Hardware Processing functions from other centers – cleaning labs, cal labs, …
» COPV testing
» Oxygen materials and components testing
• Describe the "Go To" state for SPG and PRG Guidance for PPBE 2012 submittal
» Guidance inputs provided to Hq by December 4, 2009
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Previous WSTF Analysis

- A number of analyses, reviews, and studies have been performed on WSTF and its individual capabilities and facilities.
  - » It was determined from numerous previous studies dating back to the early 1970's, that WSTF is a NASA and national asset and plays an important role in Spaceflight and Aeronautics activities.
  - » Most recent studies include
    - ➢ Center Roles and Missions Review aka "Branscome Committee" - 1993
    - ➢ Evaluations of the Impacts of Closing the Thermochemical Test Area and WSTF: H.W. Whittington- 1993

      "Actually, no significant reason to close WSTF surfaced."
    - ➢ WSTF Capabilities Review (TCB-07-03072007) - 2007
    - ➢ OCE, TCWG- 2008

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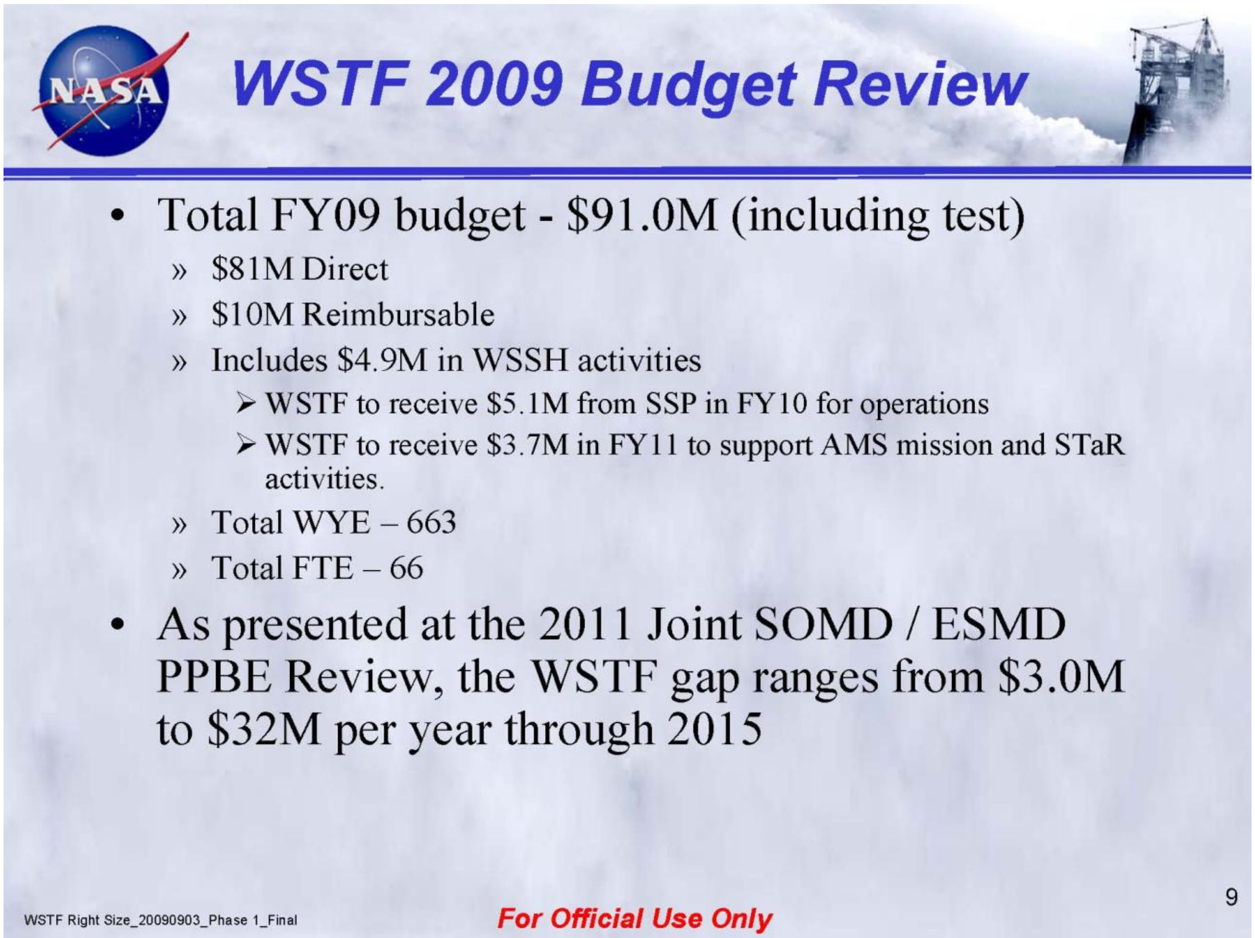
WSTF 2009 Budget Review
• Total FY09 budget - $91.0M (including test)
» $81M Direct
» $10M Reimbursable
» Includes $4.9M in WSSH activities
➢ WSTF to receive $5.1M from SSP in FY10 for operations
➢ WSTF to receive $3.7M in FY11 to support AMS mission and STaR activities.
» Total WYE – 663
» Total FTE – 66
• As presented at the 2011 Joint SOMD / ESMD PPBE Review, the WSTF gap ranges from $3.0M to $32M per year through 2015
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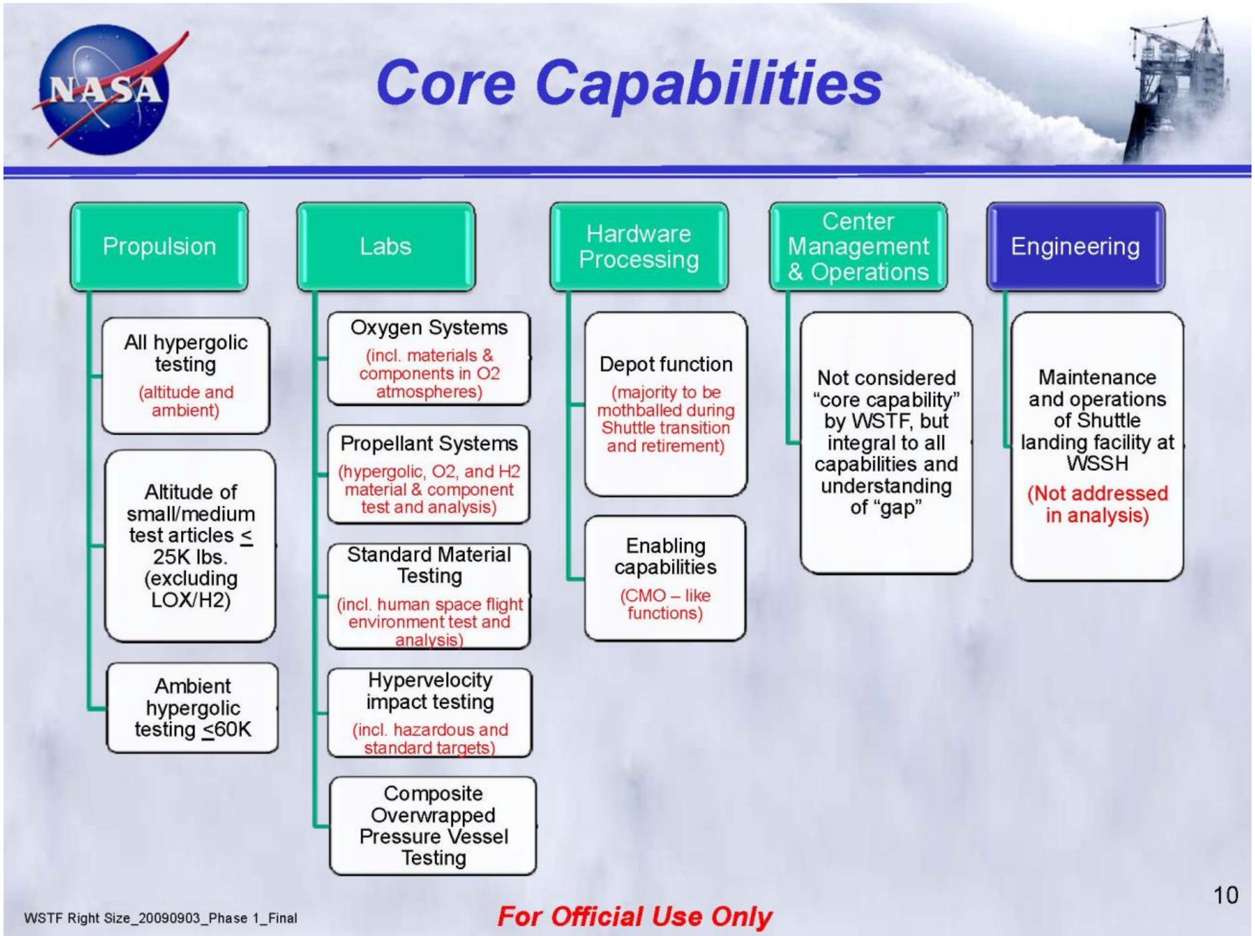
Core Capabilities
Propulsion
All hypergolic testing
(altitude and ambient)
Altitude of small/medium test articles ≤ 25K lbs. (excluding LOX/H2)
Ambient hypergolic testing ≤60K
Labs
Oxygen Systems
(incl. materials & components in O2 atmospheres)
Propellant Systems
(hypergolic, O2, and H2 material & component test and analysis)
Standard Material Testing
(incl. human space flight environment test and analysis)
Hypervelocity impact testing
(incl. hazardous and standard targets)
Composite Overwrapped Pressure Vessel Testing
Hardware Processing
Depot function
(majority to be mothballed during Shuttle transition and retirement)
Enabling capabilities
(CMO – like functions)
Center Management & Operations
Not considered "core capability" by WSTF, but integral to all capabilities and understanding of "gap"
Engineering
Maintenance and operations of Shuttle landing facility at WSSH
(Not addressed in analysis)
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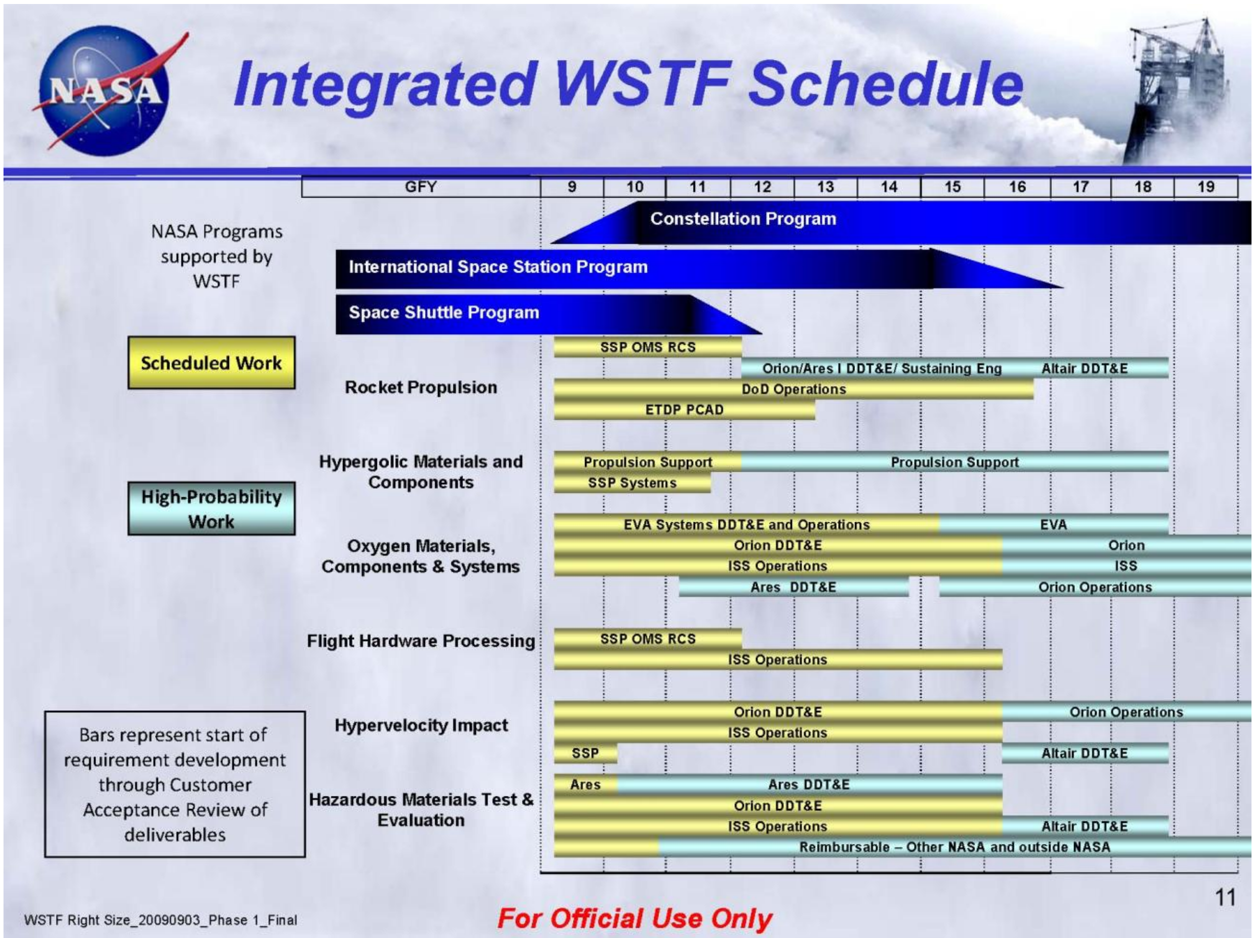

Integrated WSTF Schedule
GFY
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NASA Programs supported by WSTF
Constellation Program
International Space Station Program
Space Shuttle Program
Scheduled Work
High-Probability Work
Rocket Propulsion
SSP OMS RCS
Orion/Ares I DDT&E/ Sustaining Eng
Altair DDT&E
DoD Operations
ETDP PCAD
Hypergolic Materials and Components
Propulsion Support
Propulsion Support
SSP Systems
Oxygen Materials, Components & Systems
EVA Systems DDT&E and Operations
EVA
Orion DDT&E
Orion
ISS Operations
ISS
Ares DDT&E
Orion Operations
Flight Hardware Processing
SSP OMS RCS
ISS Operations
Hypervelocity Impact
Orion DDT&E
Orion Operations
ISS Operations
SSP
Altair DDT&E
Hazardous Materials Test & Evaluation
Ares
Ares DDT&E
Orion DDT&E
ISS Operations
Altair DDT&E
Reimbursable – Other NASA and outside NASA
Bars represent start of requirement development through Customer Acceptance Review of deliverables
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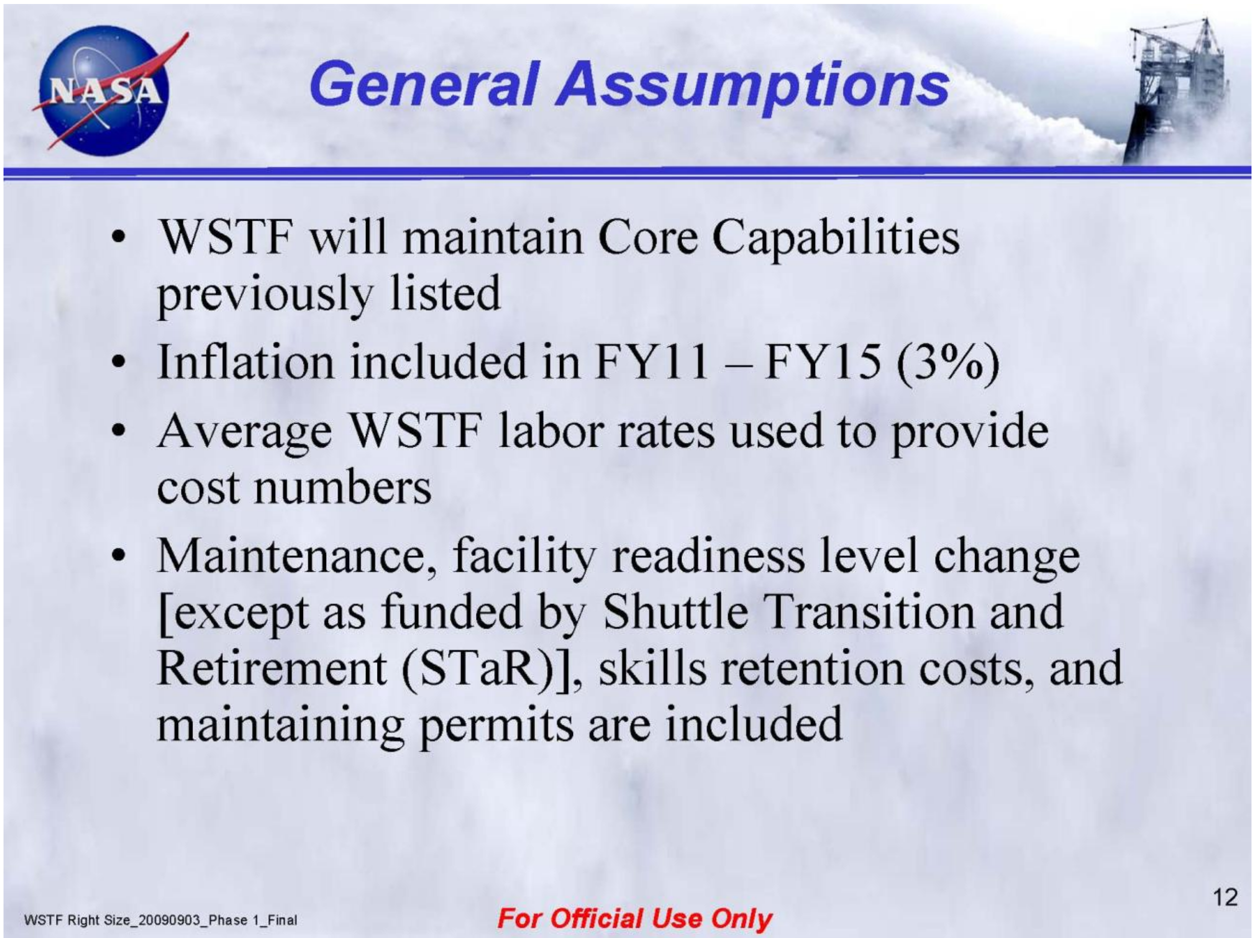

General Assumptions
• WSTF will maintain Core Capabilities previously listed
• Inflation included in FY11 – FY15 (3%)
• Average WSTF labor rates used to provide cost numbers
• Maintenance, facility readiness level change [except as funded by Shuttle Transition and Retirement (STaR)], skills retention costs, and maintaining permits are included
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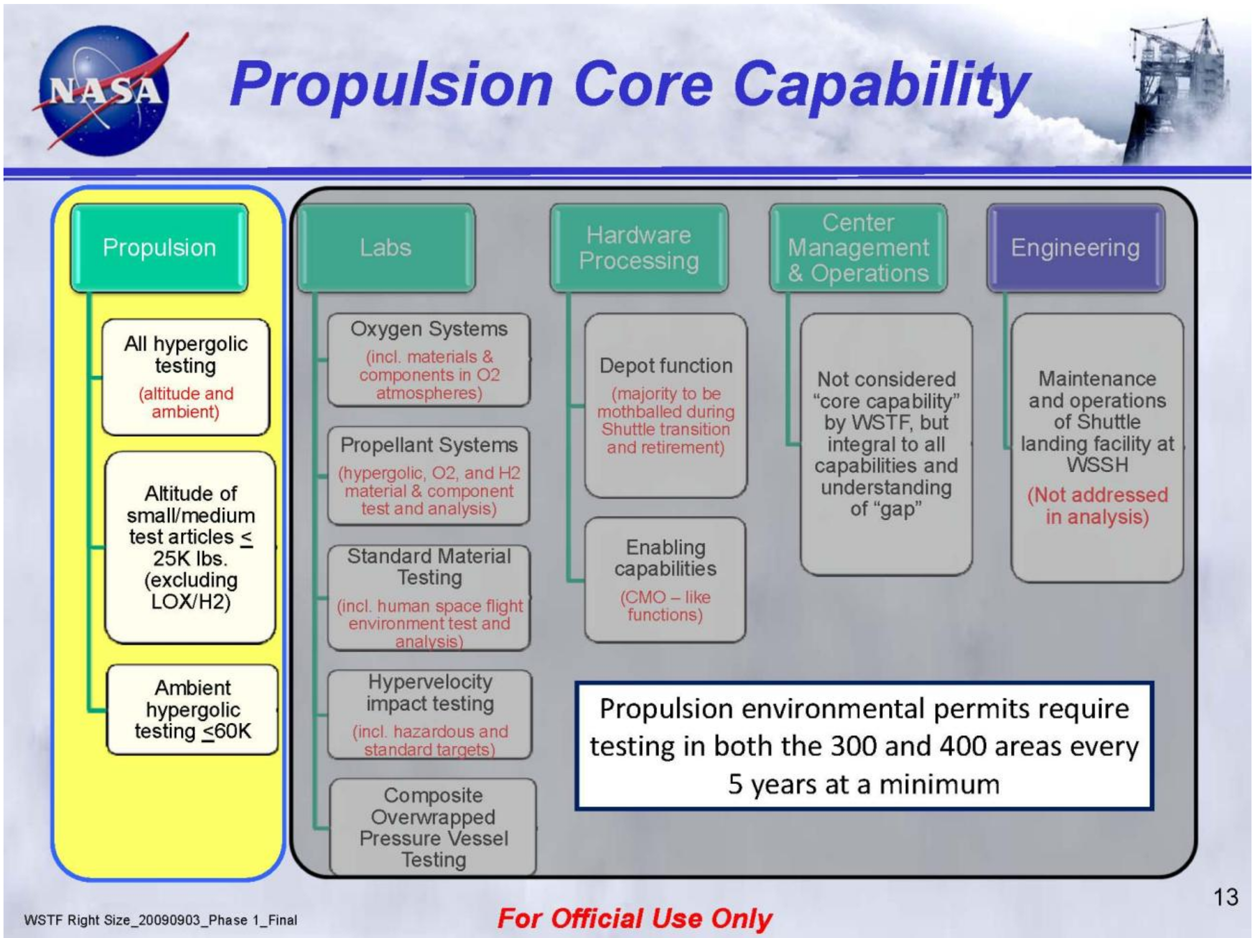
Propulsion Core Capability
Propulsion
All hypergolic testing
(altitude and ambient)
Altitude of small/medium test articles ≤ 25K lbs. (excluding LOX/H2)
Ambient hypergolic testing ≤60K
Labs
Oxygen Systems
(incl. materials & components in O2 atmospheres)
Propellant Systems
(hypergolic, O2, and H2 material & component test and analysis)
Standard Material Testing
(incl. human space flight environment test and analysis)
Hypervelocity impact testing
(incl. hazardous and standard targets)
Composite Overwrapped Pressure Vessel Testing
Hardware Processing
Depot function
(majority to be mothballed during Shuttle transition and retirement)
Enabling capabilities
(CMO – like functions)
Center Management & Operations
Not considered "core capability" by WSTF, but integral to all capabilities and understanding of "gap"
Engineering
Maintenance and operations of Shuttle landing facility at WSSH
(Not addressed in analysis)
Propulsion environmental permits require testing in both the 300 and 400 areas every 5 years at a minimum
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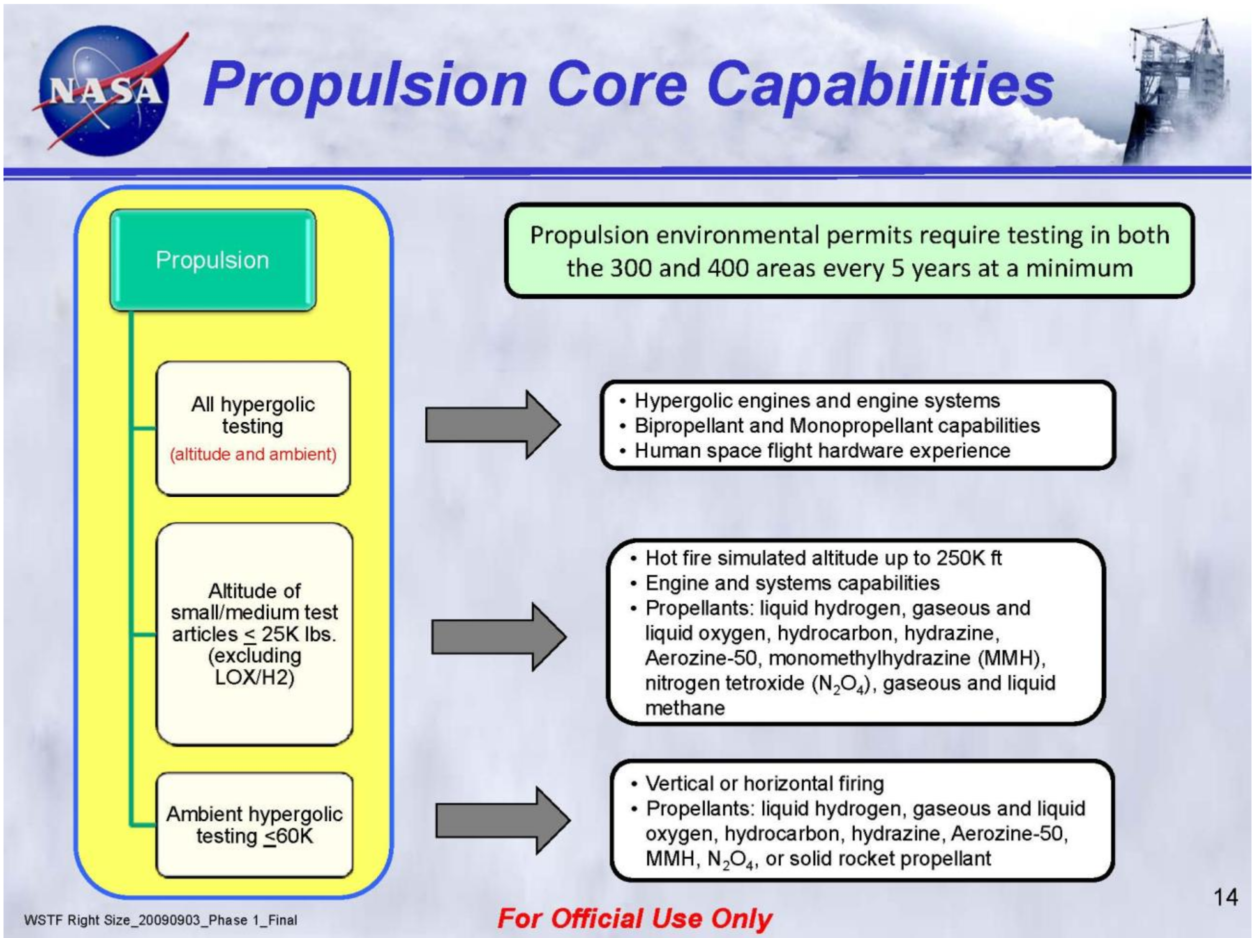
Propulsion Core Capabilities
Propulsion
Propulsion environmental permits require testing in both the 300 and 400 areas every 5 years at a minimum
All hypergolic testing (altitude and ambient)
• Hypergolic engines and engine systems
• Bipropellant and Monopropellant capabilities
• Human space flight hardware experience
Altitude of small/medium test articles ≤ 25K lbs. (excluding LOX/H2)
• Hot fire simulated altitude up to 250K ft
• Engine and systems capabilities
• Propellants: liquid hydrogen, gaseous and liquid oxygen, hydrocarbon, hydrazine, Aerozine-50, monomethylhydrazine (MMH), nitrogen tetroxide (N_2O_4), gaseous and liquid methane
Ambient hypergolic testing ≤60K
• Vertical or horizontal firing
• Propellants: liquid hydrogen, gaseous and liquid oxygen, hydrocarbon, hydrazine, Aerozine-50, MMH, N_2O_4, or solid rocket propellant
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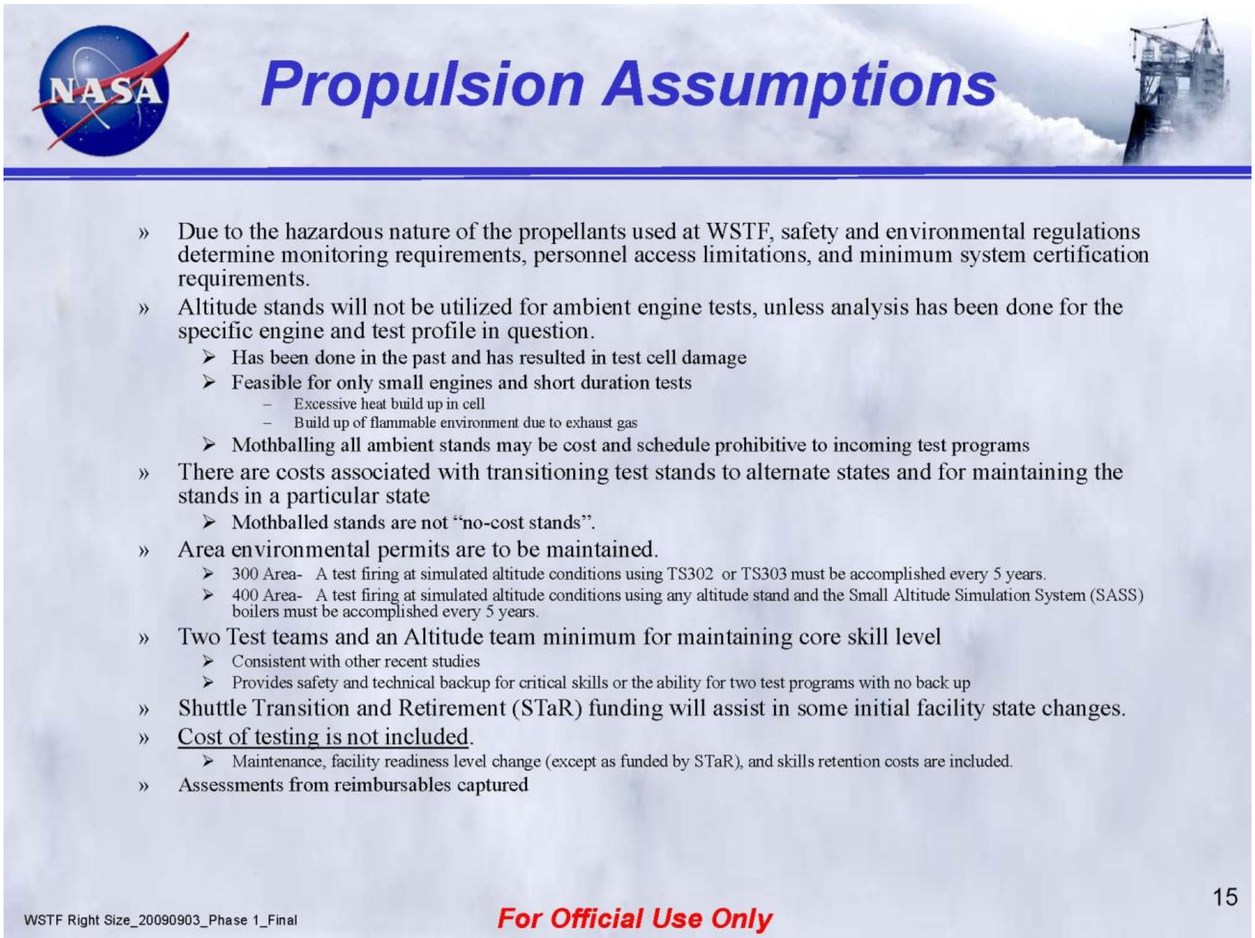
Propulsion Assumptions
» Due to the hazardous nature of the propellants used at WSTF, safety and environmental regulations determine monitoring requirements, personnel access limitations, and minimum system certification requirements.
» Altitude stands will not be utilized for ambient engine tests, unless analysis has been done for the specific engine and test profile in question.
➢ Has been done in the past and has resulted in test cell damage
➢ Feasible for only small engines and short duration tests
– Excessive heat build up in cell
– Build up of flammable environment due to exhaust gas
➢ Mothballing all ambient stands may be cost and schedule prohibitive to incoming test programs
» There are costs associated with transitioning test stands to alternate states and for maintaining the stands in a particular state
➢ Mothballed stands are not "no-cost stands".
» Area environmental permits are to be maintained.
➢ 300 Area- A test firing at simulated altitude conditions using TS302 or TS303 must be accomplished every 5 years.
➢ 400 Area- A test firing at simulated altitude conditions using any altitude stand and the Small Altitude Simulation System (SASS) boilers must be accomplished every 5 years.
» Two Test teams and an Altitude team minimum for maintaining core skill level
➢ Consistent with other recent studies
➢ Provides safety and technical backup for critical skills or the ability for two test programs with no back up
» Shuttle Transition and Retirement (STaR) funding will assist in some initial facility state changes.
» Cost of testing is not included.
➢ Maintenance, facility readiness level change (except as funded by STaR), and skills retention costs are included.
» Assessments from reimbursables captured
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Propulsion Budget Summary

FY	Total In-Guide Maintenance		Meet Commitments And Maintain Core	
	Funding (K)	WYE	Cost (K) (delta In-guide)	WYE
FY10	**$4,764**	**35**	$4,554 $210	36
FY11	$4,718	35	$4,774 ($56)	37
FY12	$4,772	35	$5,632 ($860)	43
FY13	$4,422	34	$6,247 ($1,825)	47
FY14	$4,422	34	$6,651 ($2,229)	49
FY15	$4,422	34	$6,802 ($2,380)	49
6 Yr Total	$27,520		$34,660 ($7,140)	

Propulsion reduction from 110 to and average of 44 WYEs (60%) and to 3 of 9 test stands

- Currently 110 WYE
- 3% Inflation included starting FY11
- Numbers do not include test personnel for active test programs, or enabling capability costs associated with testing
- CMO assessment would eliminate FY10 surplus. (Recommend assessments end in al FY11)
- Assumes 30% sharing of Test Crew during extended our-year times of no testing (not applicable if testing occurs

CMO Assessment negatively affects ability of Programs & Projects to fund propulsion infrastructure

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Meeting Propulsion Commitments and Maintaining Core

	Baseline FY09	FY10	FY11	FY12	FY13	FY14	FY15
TS 301 Ambient			STaR	AA	AA	AA	AA
TS 302 Altitude			MOTHBALLED				
TS 303 Altitude		STaR	IS	IS	IS	IS	SR
TS 328 Ambient			MB	MB	MB	MB	MB
TS 401 Altitude							
TS 402 Ambient			MOTHBALLED				
TS 403 Altitude			STaR			AA	AA
TS 405 Altitude			STaR	MB	MB	MB	MB
TS 406 Altitude			STaR	MB	MB	MB	MB

LEGEND

- Active Occupied
- Active Available
- Inactive Standby
- Mothball
- Transition

STaR – Shuttle Transition and Retirement

SR – Skills Retention

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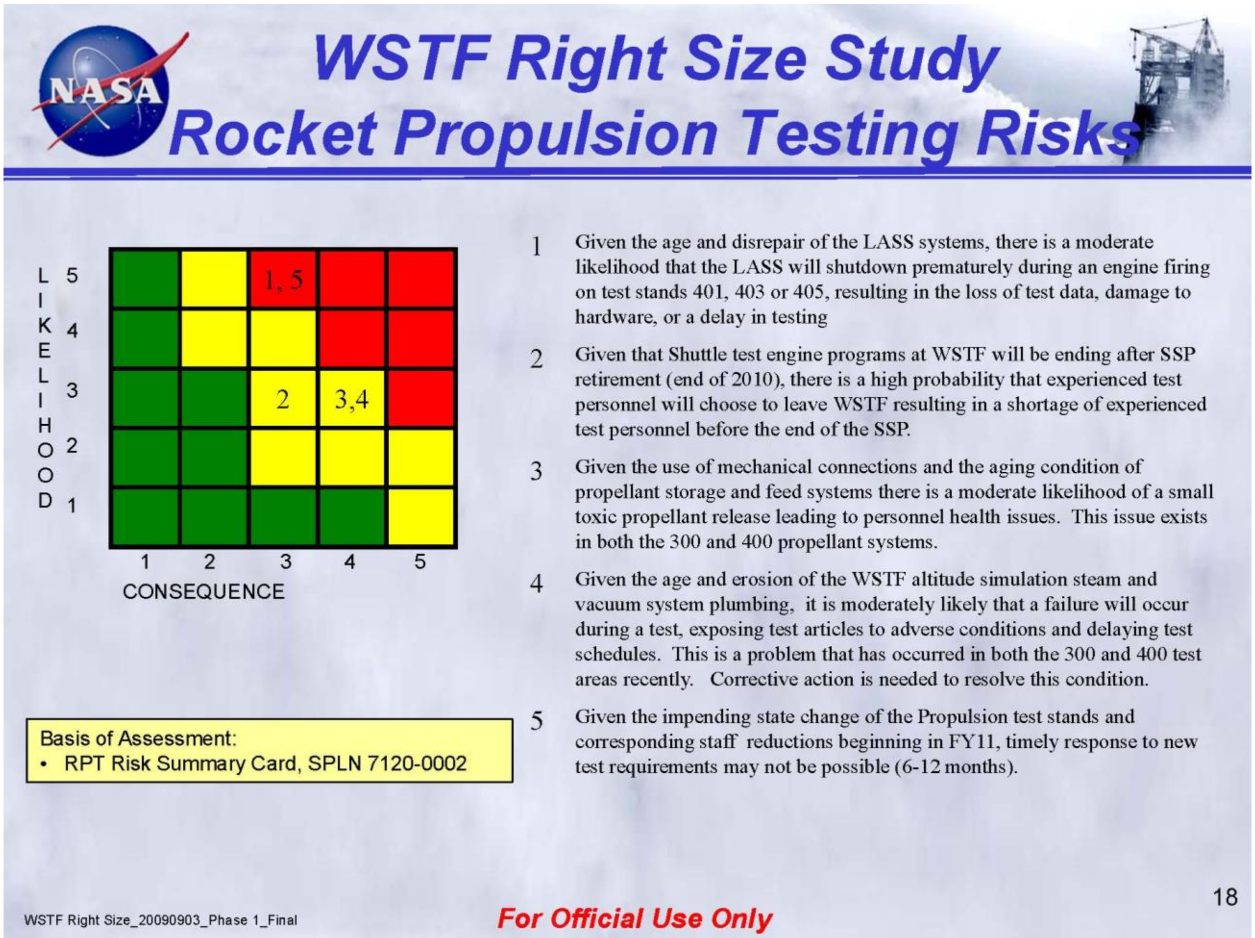
WSTF Right Size Study
Rocket Propulsion Testing Risks
LIKELIHOOD
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CONSEQUENCE
1 Given the age and disrepair of the LASS systems, there is a moderate likelihood that the LASS will shutdown prematurely during an engine firing on test stands 401, 403 or 405, resulting in the loss of test data, damage to hardware, or a delay in testing
2 Given that Shuttle test engine programs at WSTF will be ending after SSP retirement (end of 2010), there is a high probability that experienced test personnel will choose to leave WSTF resulting in a shortage of experienced test personnel before the end of the SSP.
3 Given the use of mechanical connections and the aging condition of propellant storage and feed systems there is a moderate likelihood of a small toxic propellant release leading to personnel health issues. This issue exists in both the 300 and 400 propellant systems.
4 Given the age and erosion of the WSTF altitude simulation steam and vacuum system plumbing, it is moderately likely that a failure will occur during a test, exposing test articles to adverse conditions and delaying test schedules. This is a problem that has occurred in both the 300 and 400 test areas recently. Corrective action is needed to resolve this condition.
5 Given the impending state change of the Propulsion test stands and corresponding staff reductions beginning in FY11, timely response to new test requirements may not be possible (6-12 months).
Basis of Assessment:
• RPT Risk Summary Card, SPLN 7120-0002
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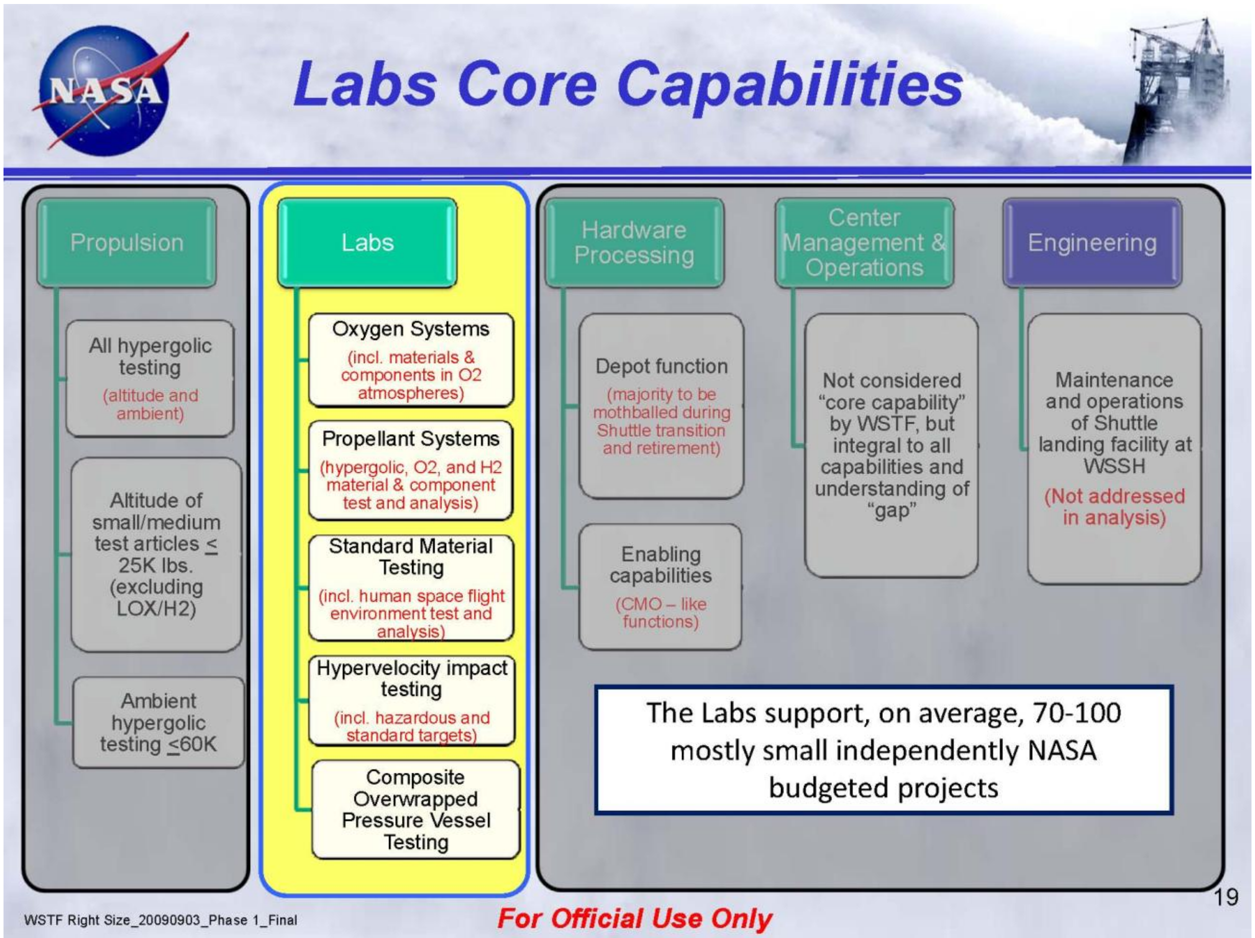
Labs Core Capabilities
Propulsion
All hypergolic testing
(altitude and ambient)
Altitude of small/medium test articles ≤ 25K lbs. (excluding LOX/H2)
Ambient hypergolic testing ≤60K
Labs
Oxygen Systems
(incl. materials & components in O2 atmospheres)
Propellant Systems
(hypergolic, O2, and H2 material & component test and analysis)
Standard Material Testing
(incl. human space flight environment test and analysis)
Hypervelocity impact testing
(incl. hazardous and standard targets)
Composite Overwrapped Pressure Vessel Testing
Hardware Processing
Depot function
(majority to be mothballed during Shuttle transition and retirement)
Enabling capabilities
(CMO – like functions)
Center Management & Operations
Not considered "core capability" by WSTF, but integral to all capabilities and understanding of "gap"
Engineering
Maintenance and operations of Shuttle landing facility at WSSH
(Not addressed in analysis)
The Labs support, on average, 70-100 mostly small independently NASA budgeted projects
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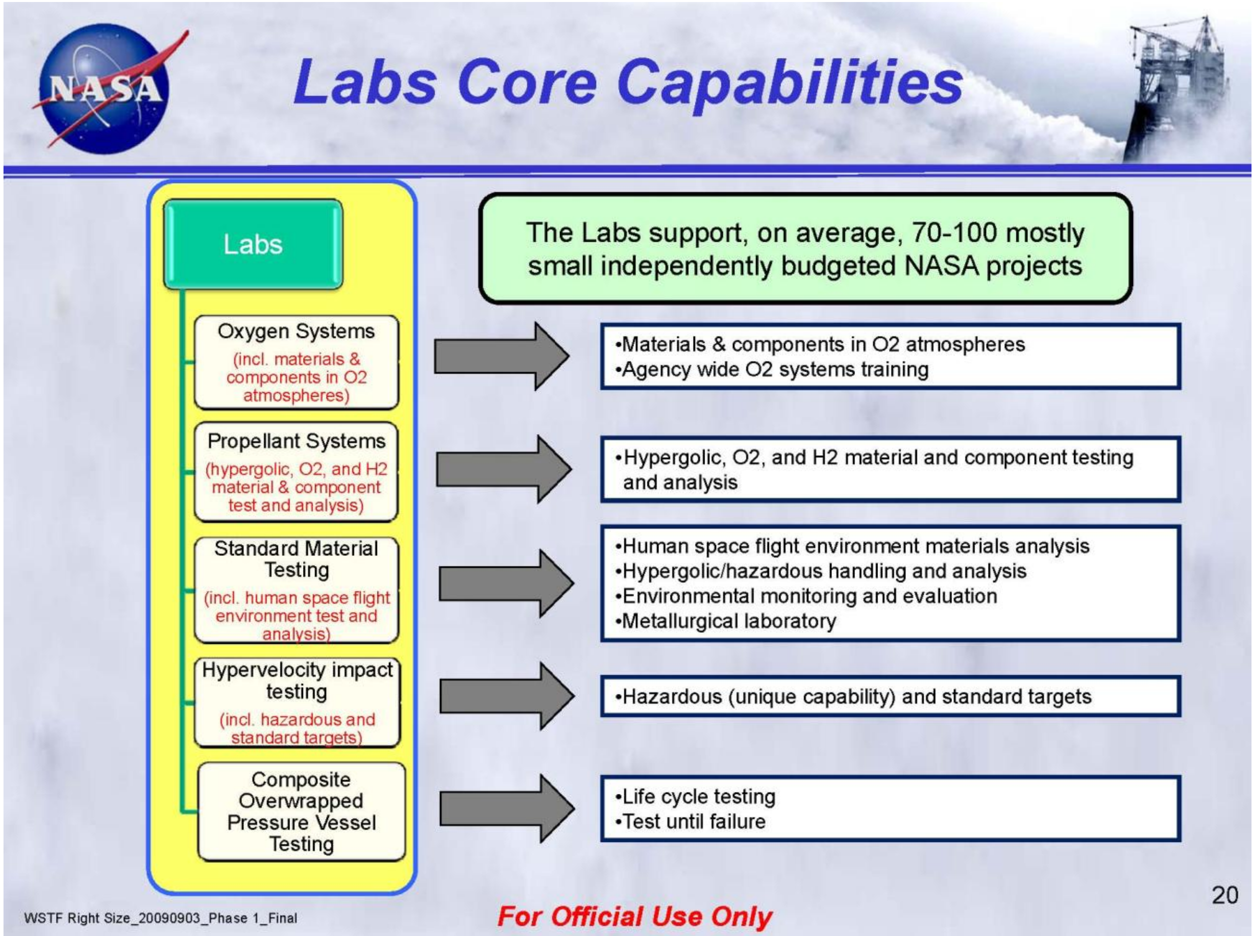
Labs Core Capabilities
Labs
The Labs support, on average, 70-100 mostly small independently budgeted NASA projects
Oxygen Systems
(incl. materials & components in O2 atmospheres)
•Materials & components in O2 atmospheres
•Agency wide O2 systems training
Propellant Systems
(hypergolic, O2, and H2 material & component test and analysis)
•Hypergolic, O2, and H2 material and component testing and analysis
Standard Material Testing
(incl. human space flight environment test and analysis)
•Human space flight environment materials analysis
•Hypergolic/hazardous handling and analysis
•Environmental monitoring and evaluation
•Metallurgical laboratory
Hypervelocity impact testing
(incl. hazardous and standard targets)
•Hazardous (unique capability) and standard targets
Composite Overwrapped Pressure Vessel Testing
•Life cycle testing
•Test until failure
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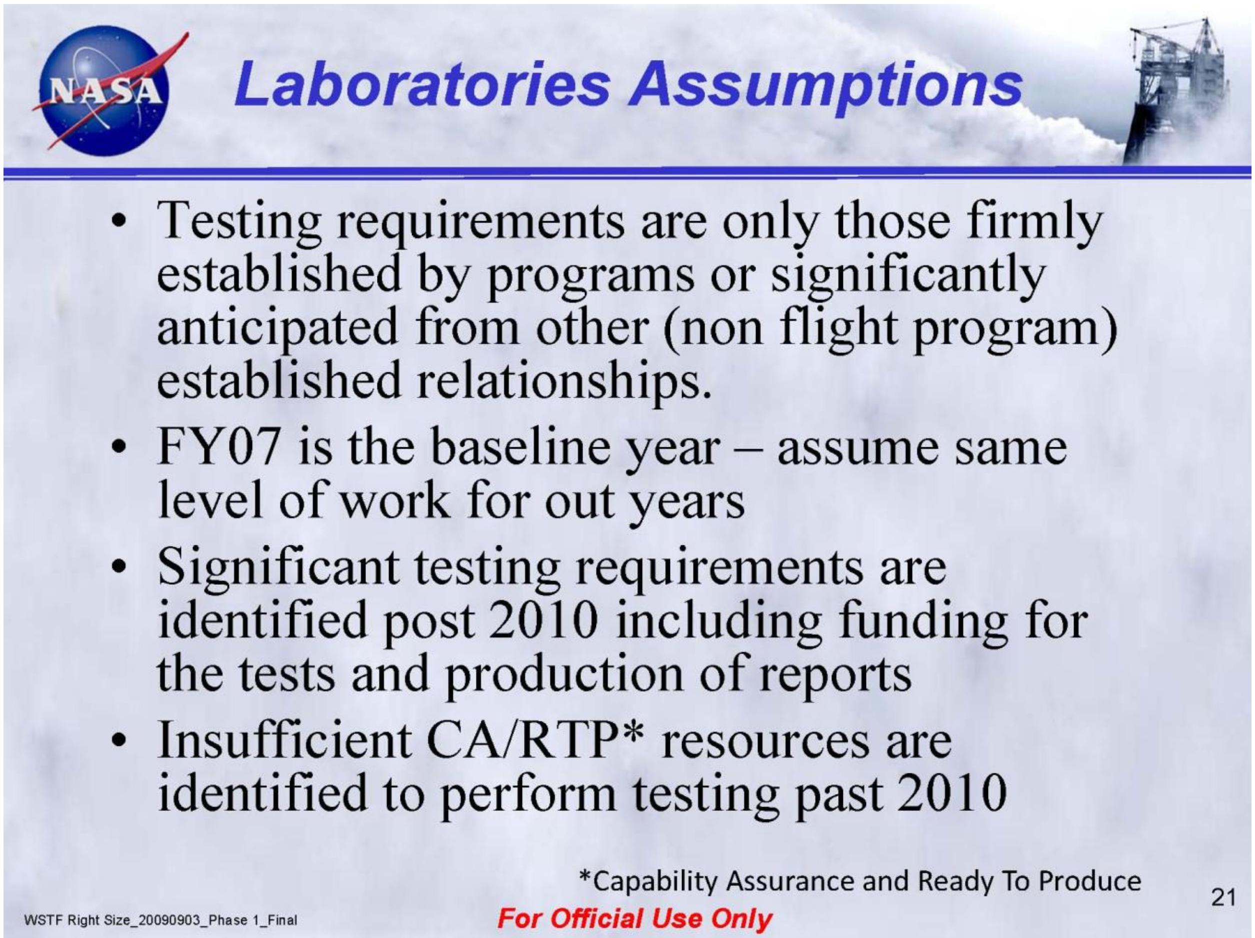

Laboratories Assumptions
• Testing requirements are only those firmly established by programs or significantly anticipated from other (non flight program) established relationships.
• FY07 is the baseline year – assume same level of work for out years
• Significant testing requirements are identified post 2010 including funding for the tests and production of reports
• Insufficient CA/RTP* resources are identified to perform testing past 2010
*Capability Assurance and Ready To Produce
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Laboratories Budget Summary

FY	Total In-Guide		Testing Requirements	RTP and CA Requirements	Total WYE Needed	Total Requirements (Delta from In-Guide)
	Funding (K)	WYE	Cost (K)	Cost (K)	WYE	Cost (K) (delta In-guide)
FY10	$10,326	61	$4,563	$5,223	70	$9,943 $692
FY11	$6,643	38	$2,992	$5,380	71	$8,372 ($1,729)
FY12	$5,454	30	$2,833	$5,541	61	$8,374 ($2,920)
FY13	$5,657	31	$2,936	$5,708	61	$8,644 ($2,987)
FY14	$5,555	29	$2,865	$5,879	60	$8,744 ($3,189)
FY15	$5,572	28	$2,854	$6,055	59	$8,909 ($3,337)
6 Yr Total	$39,207		$19,043	$33,633		$52,676 ($13,469)

- Currently 94WYE
- 3% Inflation included starting in FY11
- CMO assessment would eliminate FY10 surplus. (Recommend assessments end in al FY11)

Laboratories reduction from 78 to and average of 64 WYEs (18%)

CMO Assessment negatively affects ability of Programs & Projects to fund propulsion infrastructure

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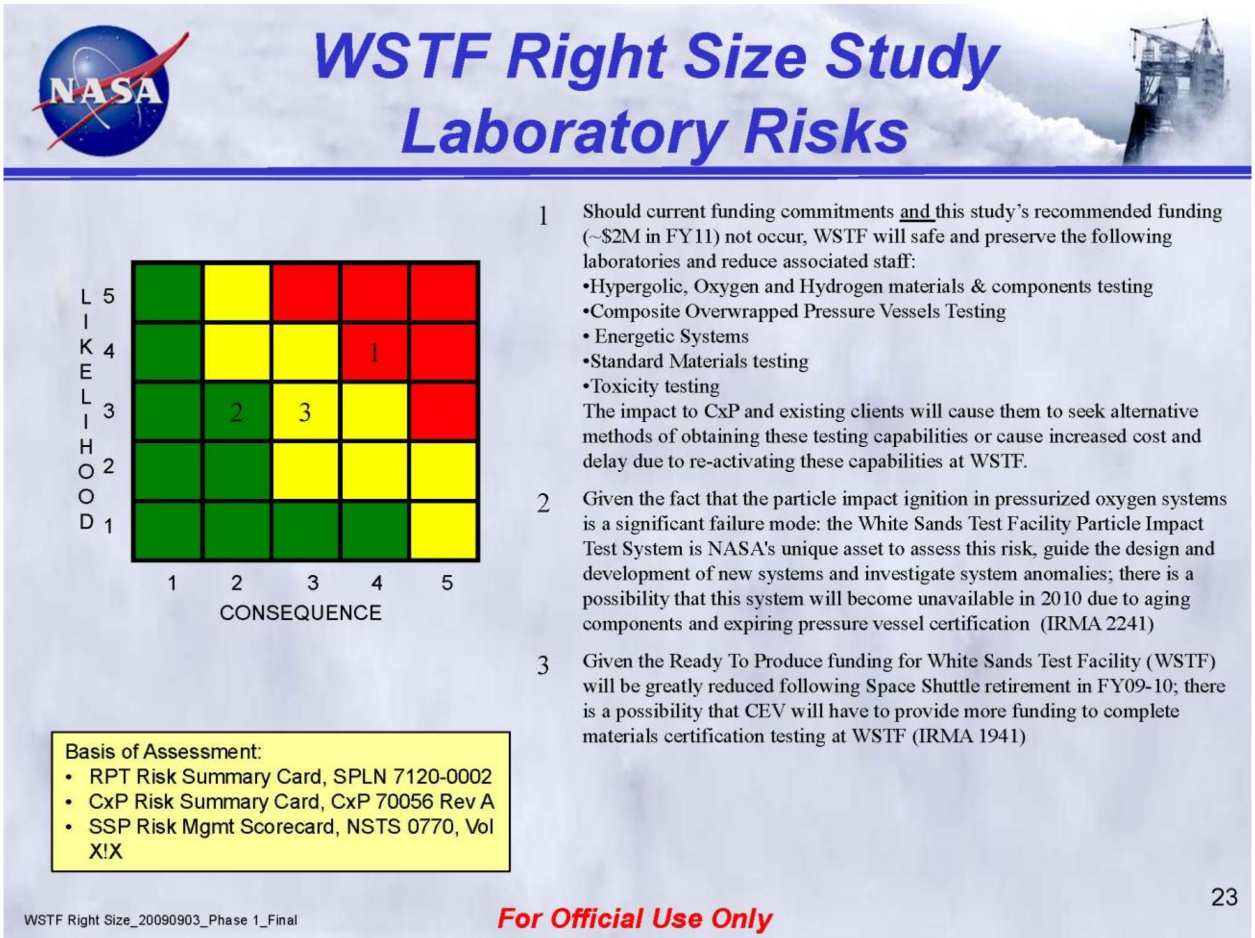
WSTF Right Size Study
Laboratory Risks
LIKELIHOOD
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CONSEQUENCE
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3
Basis of Assessment:
• RPT Risk Summary Card, SPLN 7120-0002
• CxP Risk Summary Card, CxP 70056 Rev A
• SSP Risk Mgmt Scorecard, NSTS 0770, Vol X!X
1 Should current funding commitments and this study's recommended funding (~$2M in FY11) not occur, WSTF will safe and preserve the following laboratories and reduce associated staff:
•Hypergolic, Oxygen and Hydrogen materials & components testing
•Composite Overwrapped Pressure Vessels Testing
• Energetic Systems
•Standard Materials testing
•Toxicity testing
The impact to CxP and existing clients will cause them to seek alternative methods of obtaining these testing capabilities or cause increased cost and delay due to re-activating these capabilities at WSTF.
2 Given the fact that the particle impact ignition in pressurized oxygen systems is a significant failure mode: the White Sands Test Facility Particle Impact Test System is NASA's unique asset to assess this risk, guide the design and development of new systems and investigate system anomalies; there is a possibility that this system will become unavailable in 2010 due to aging components and expiring pressure vessel certification (IRMA 2241)
3 Given the Ready To Produce funding for White Sands Test Facility (WSTF) will be greatly reduced following Space Shuttle retirement in FY09-10; there is a possibility that CEV will have to provide more funding to complete materials certification testing at WSTF (IRMA 1941)
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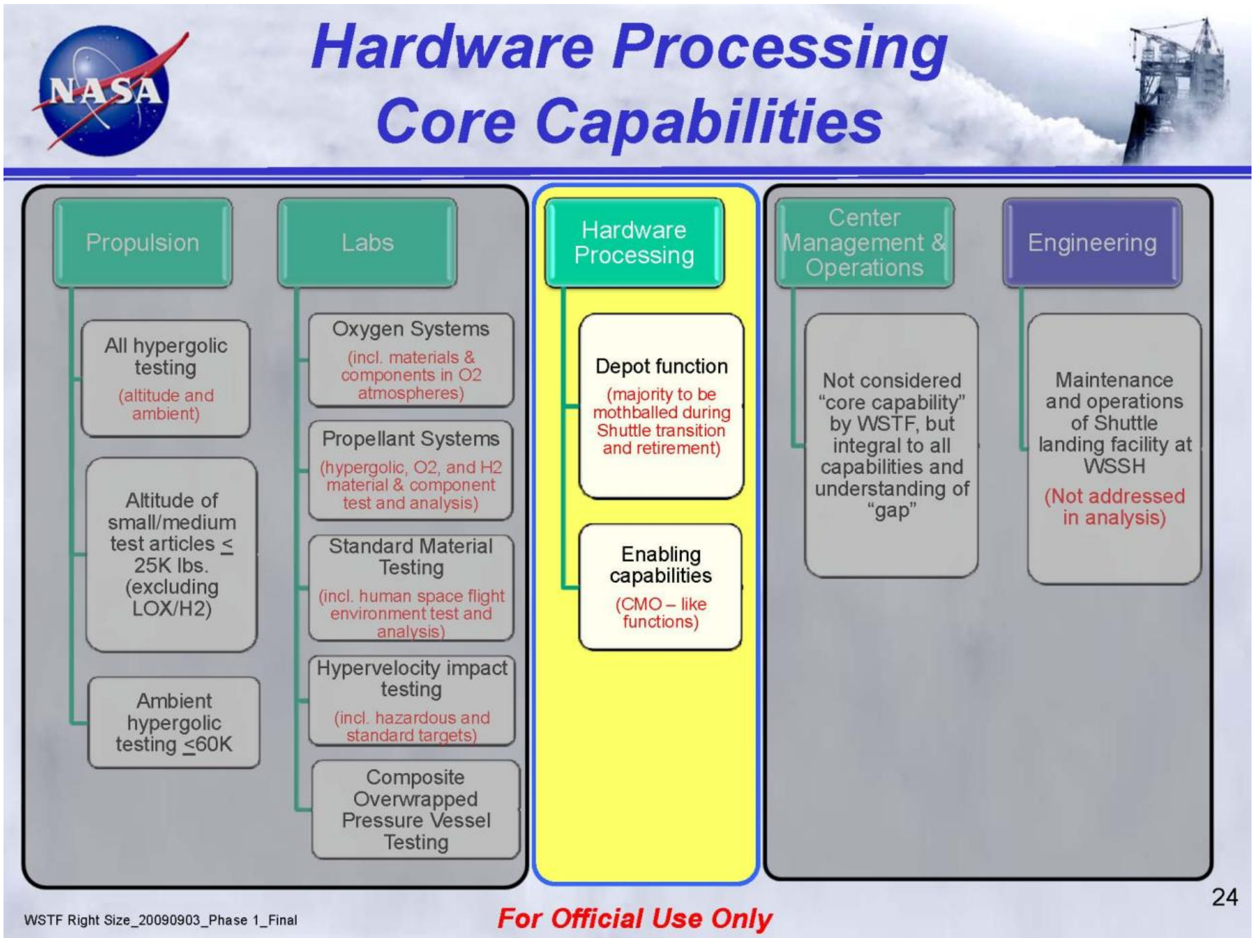

Hardware Processing
Core Capabilities
Propulsion
Labs
Hardware Processing
Center Management & Operations
Engineering
All hypergolic testing
(altitude and ambient)
Altitude of small/medium test articles ≤ 25K lbs. (excluding LOX/H2)
Ambient hypergolic testing ≤60K
Oxygen Systems
(incl. materials & components in O2 atmospheres)
Propellant Systems
(hypergolic, O2, and H2 material & component test and analysis)
Standard Material Testing
(incl. human space flight environment test and analysis)
Hypervelocity impact testing
(incl. hazardous and standard targets)
Composite Overwrapped Pressure Vessel Testing
Depot function
(majority to be mothballed during Shuttle transition and retirement)
Enabling capabilities
(CMO – like functions)
Not considered "core capability" by WSTF, but integral to all capabilities and understanding of "gap"
Maintenance and operations of Shuttle landing facility at WSSH
(Not addressed in analysis)
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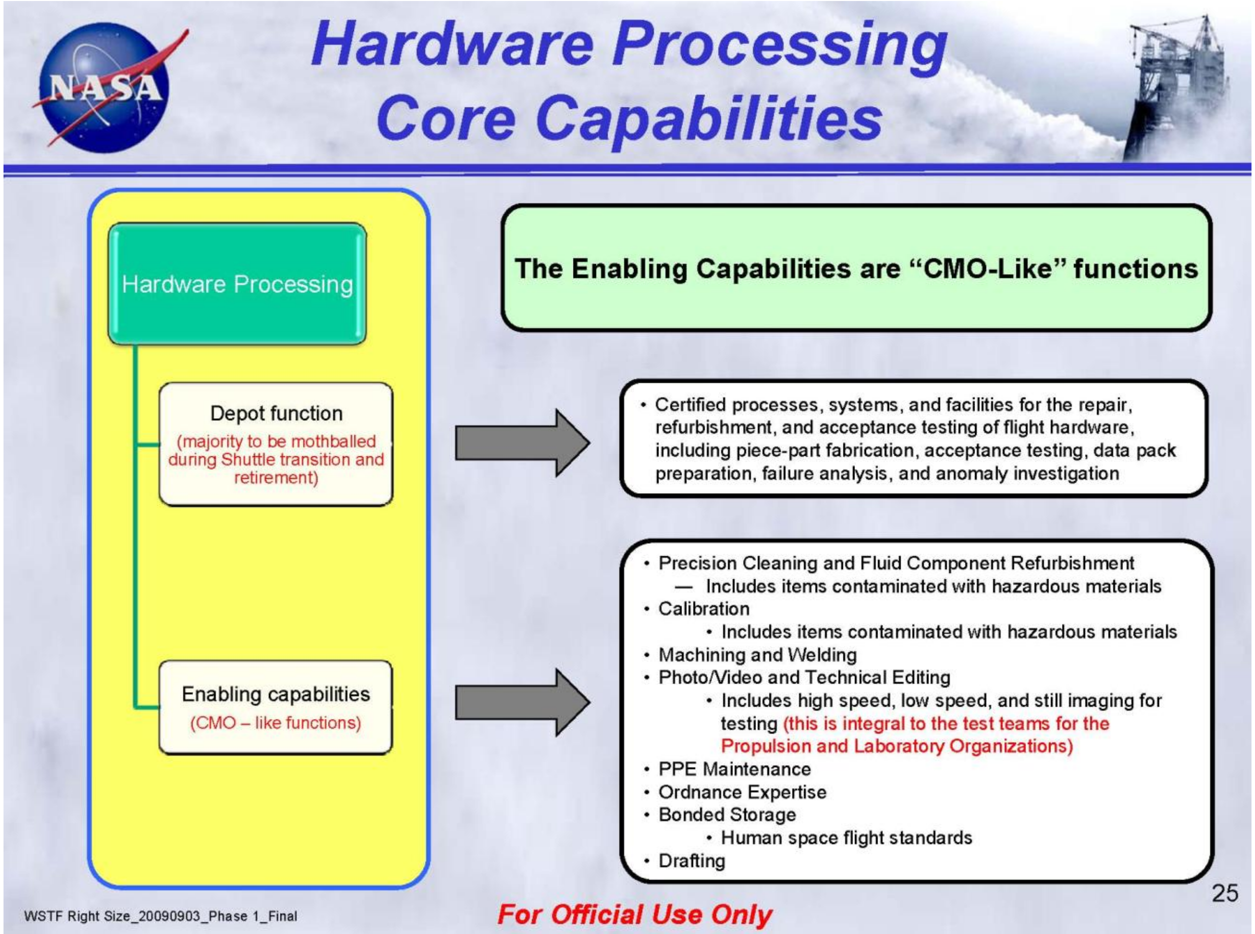
Hardware Processing
Core Capabilities
Hardware Processing
Depot function
(majority to be mothballed during Shuttle transition and retirement)
Enabling capabilities
(CMO – like functions)
The Enabling Capabilities are "CMO-Like" functions
• Certified processes, systems, and facilities for the repair, refurbishment, and acceptance testing of flight hardware, including piece-part fabrication, acceptance testing, data pack preparation, failure analysis, and anomaly investigation
• Precision Cleaning and Fluid Component Refurbishment
— Includes items contaminated with hazardous materials
• Calibration
• Includes items contaminated with hazardous materials
• Machining and Welding
• Photo/Video and Technical Editing
• Includes high speed, low speed, and still imaging for testing (this is integral to the test teams for the Propulsion and Laboratory Organizations)
• PPE Maintenance
• Ordnance Expertise
• Bonded Storage
• Human space flight standards
• Drafting
25
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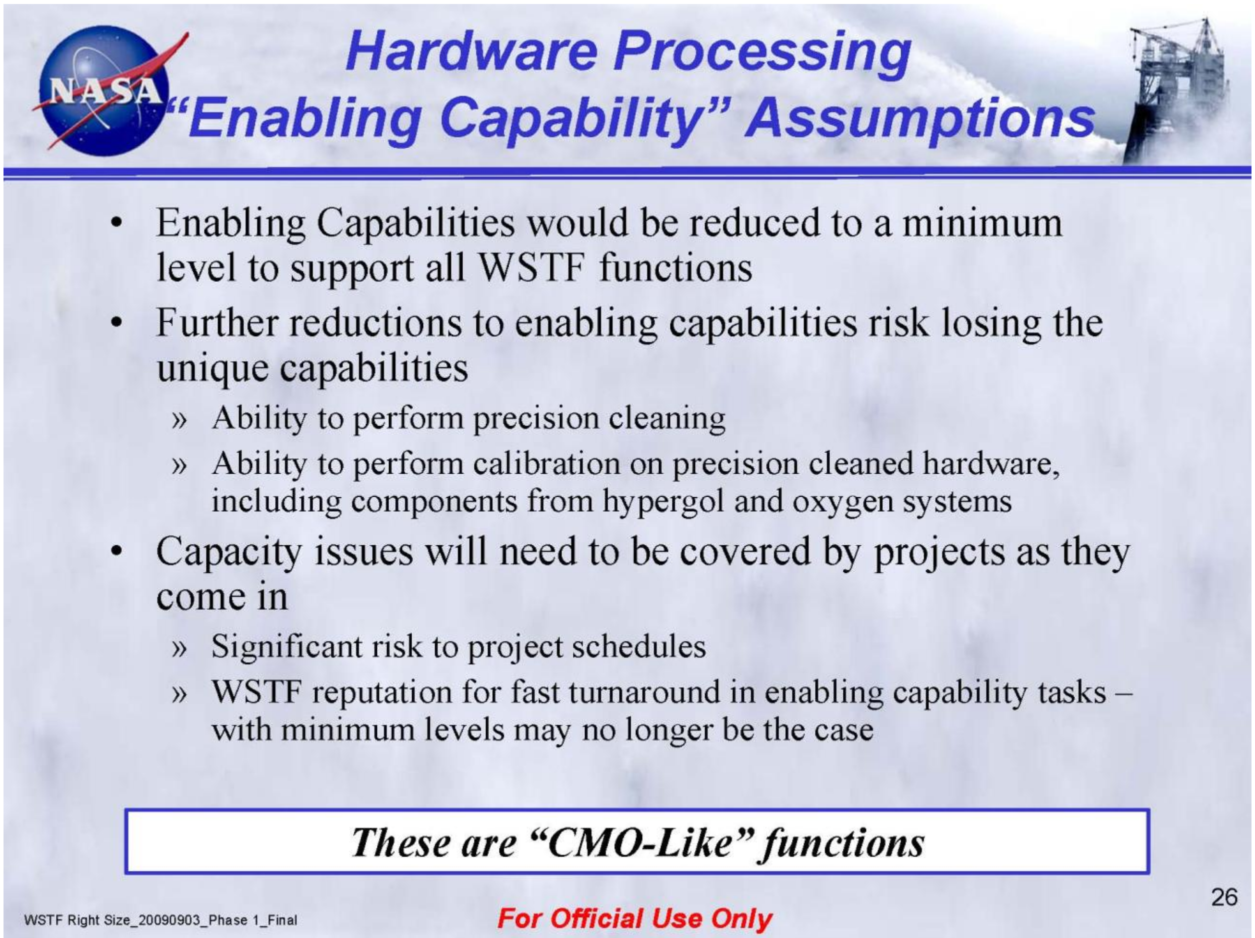
Hardware Processing
"Enabling Capability" Assumptions
• Enabling Capabilities would be reduced to a minimum level to support all WSTF functions
• Further reductions to enabling capabilities risk losing the unique capabilities
» Ability to perform precision cleaning
» Ability to perform calibration on precision cleaned hardware, including components from hypergol and oxygen systems
• Capacity issues will need to be covered by projects as they come in
» Significant risk to project schedules
» WSTF reputation for fast turnaround in enabling capability tasks – with minimum levels may no longer be the case
These are "CMO-Like" functions
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Hardware Processing "Depot" Assumptions

- Flight Hardware Processing is primarily performed in the Depot facilities. These facilities and associated operations are scaling down due to SSP retirement
  - » Continue to process ISS hardware
    - ➢ Currently process the Respiratory Support Pack (2 every 2 years) and the Oxygen Recharge Compressor Assembly (ORCA)
    - ➢ Because ORCA transfers O2 from the shuttle, the ORCA refurbishment will not be required following SSP retirement.
    - ➢ Questions exist related with continuation of RSP refurbishment. The RSP has only once been manifested on a Progress and suffered a failure that was attributed to the different launch vibration environment. Redesign of the RSP has been mentioned but no word on progress. Some version of RSP will be needed on ISS and this hardware will require O2 wetting ATP prior to launch at a minimum.
  - » Retire facilities associated with repair and acceptance test of SSP hypergol subsystem assemblies (primary/vernier thrusters, OMS engines, Parker components, quad check valve, and their components) and the ATP facilities used solely for SSP main propulsion hydrogen assemblies and life support panels (LHRP, HFCV, and ARPCS supply and control panels).
    - ➢ 51 WYE affected
    - ➢ $6M Budget retired
    - ➢ $$ associated with STaR are not included. WSTF STaR activities are not broken down to identify planned expenditures in Depot separately from overall WSTF activities.

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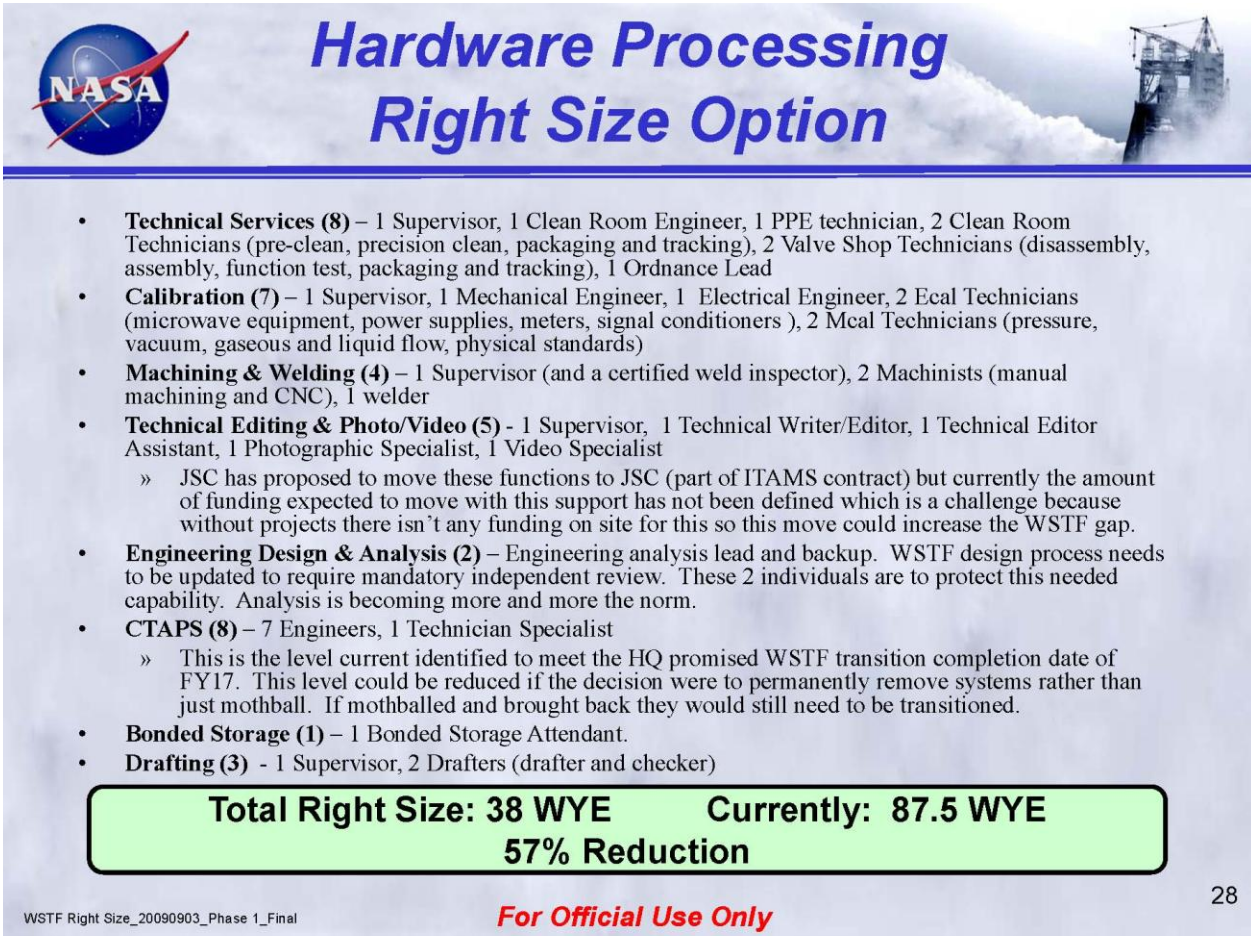
Hardware Processing
Right Size Option
• Technical Services (8) – 1 Supervisor, 1 Clean Room Engineer, 1 PPE technician, 2 Clean Room Technicians (pre-clean, precision clean, packaging and tracking), 2 Valve Shop Technicians (disassembly, assembly, function test, packaging and tracking), 1 Ordnance Lead
• Calibration (7) – 1 Supervisor, 1 Mechanical Engineer, 1 Electrical Engineer, 2 Ecal Technicians (microwave equipment, power supplies, meters, signal conditioners), 2 Mcal Technicians (pressure, vacuum, gaseous and liquid flow, physical standards)
• Machining & Welding (4) – 1 Supervisor (and a certified weld inspector), 2 Machinists (manual machining and CNC), 1 welder
• Technical Editing & Photo/Video (5) - 1 Supervisor, 1 Technical Writer/Editor, 1 Technical Editor Assistant, 1 Photographic Specialist, 1 Video Specialist
» JSC has proposed to move these functions to JSC (part of ITAMS contract) but currently the amount of funding expected to move with this support has not been defined which is a challenge because without projects there isn't any funding on site for this so this move could increase the WSTF gap.
• Engineering Design & Analysis (2) – Engineering analysis lead and backup. WSTF design process needs to be updated to require mandatory independent review. These 2 individuals are to protect this needed capability. Analysis is becoming more and more the norm.
• CTAPS (8) – 7 Engineers, 1 Technician Specialist
» This is the level current identified to meet the HQ promised WSTF transition completion date of FY17. This level could be reduced if the decision were to permanently remove systems rather than just mothball. If mothballed and brought back they would still need to be transitioned.
• Bonded Storage (1) – 1 Bonded Storage Attendant.
• Drafting (3) - 1 Supervisor, 2 Drafters (drafter and checker)
Total Right Size: 38 WYE Currently: 87.5 WYE
57% Reduction
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Hardware Processing Budget Summary

FY	Funding Available		Depot Maintenance				Enabling Capabilities			
	Funding (K)	WYE	Funding (K)	WYE	Min (K) (delta)	WYE (delta)	Funding (K)	WYE	Min (K) (delta)	WYE (delta)
FY08-09 Avg.	$8,320	104	$ 1,800	16			$ 6,520	88		
FY10	$6,581 $183	60	$1,700	16	$1,700 $0	23 (8)	$4,881	44	$4,698 $183	38 6
FY11	$3,529 ($1,655)	32	$325	3	$345 ($20)	5 (2)	$3,204	29	$4,839 ($1,635)	38 (9)
FY12	$2,820 ($2,519)	26	$75	1	$355 ($280)	5 (4)	$2,745	25	$4,984 ($2,239)	38 (13)
FY13	$2,654 ($2,844)	24	$25	0.25	$365 ($340)	5 (4.75)	$2,629	24	$5,133 ($2,504)	38 (14)
FY14	$2,518 ($3,145)	23	$75	1	$376 ($301)	5 (4)	$2,443	22	$5,287 ($2,844)	38 (16)
FY15	$2,463 ($3,371)	22	$25	0.25	$388 ($363)	5 (4.75)	$2,438	22	$5,446 ($3,008)	38 (16)
6 Yr Total	$20,565 ($13,351)		$2,225		$3,529 ($1,304)		$18,340		$30,387 ($12,047)	

- Currently 94WYE
- 3% Inflation included
- Assumes equivalent amount of work from Propulsion and Laboratories
- Enabling Capability minimum costs provide very basic capacity, additional capacity will be program/project responsibility

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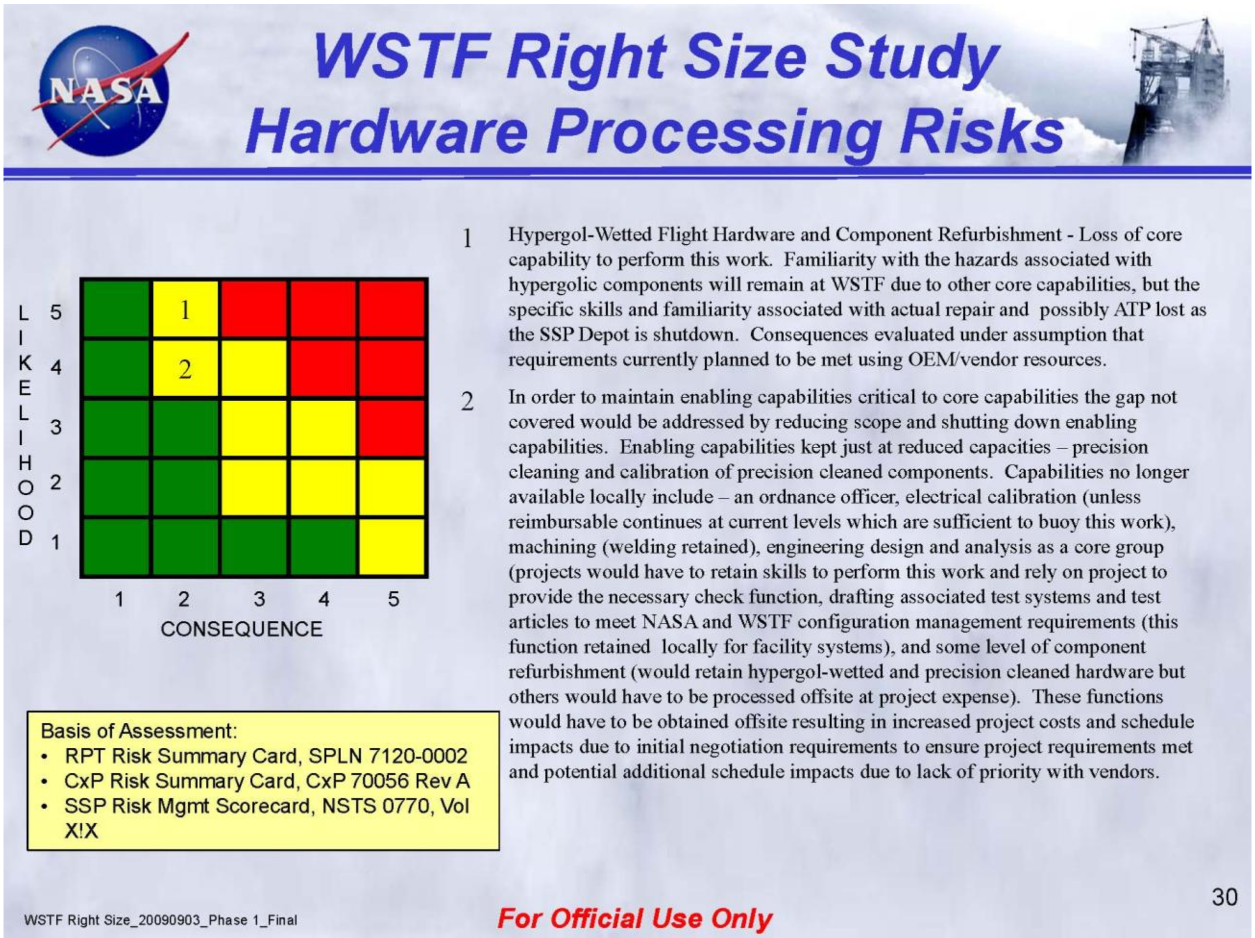
WSTF Right Size Study
Hardware Processing Risks
LIKELIHOOD
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CONSEQUENCE
1 Hypergol-Wetted Flight Hardware and Component Refurbishment - Loss of core capability to perform this work. Familiarity with the hazards associated with hypergolic components will remain at WSTF due to other core capabilities, but the specific skills and familiarity associated with actual repair and possibly ATP lost as the SSP Depot is shutdown. Consequences evaluated under assumption that requirements currently planned to be met using OEM/vendor resources.
2 In order to maintain enabling capabilities critical to core capabilities the gap not covered would be addressed by reducing scope and shutting down enabling capabilities. Enabling capabilities kept just at reduced capacities – precision cleaning and calibration of precision cleaned components. Capabilities no longer available locally include – an ordnance officer, electrical calibration (unless reimbursable continues at current levels which are sufficient to buoy this work), machining (welding retained), engineering design and analysis as a core group (projects would have to retain skills to perform this work and rely on project to provide the necessary check function, drafting associated test systems and test articles to meet NASA and WSTF configuration management requirements (this function retained locally for facility systems), and some level of component refurbishment (would retain hypergol-wetted and precision cleaned hardware but others would have to be processed offsite at project expense). These functions would have to be obtained offsite resulting in increased project costs and schedule impacts due to initial negotiation requirements to ensure project requirements met and potential additional schedule impacts due to lack of priority with vendors.
Basis of Assessment:
• RPT Risk Summary Card, SPLN 7120-0002
• CxP Risk Summary Card, CxP 70056 Rev A
• SSP Risk Mgmt Scorecard, NSTS 0770, Vol X!X
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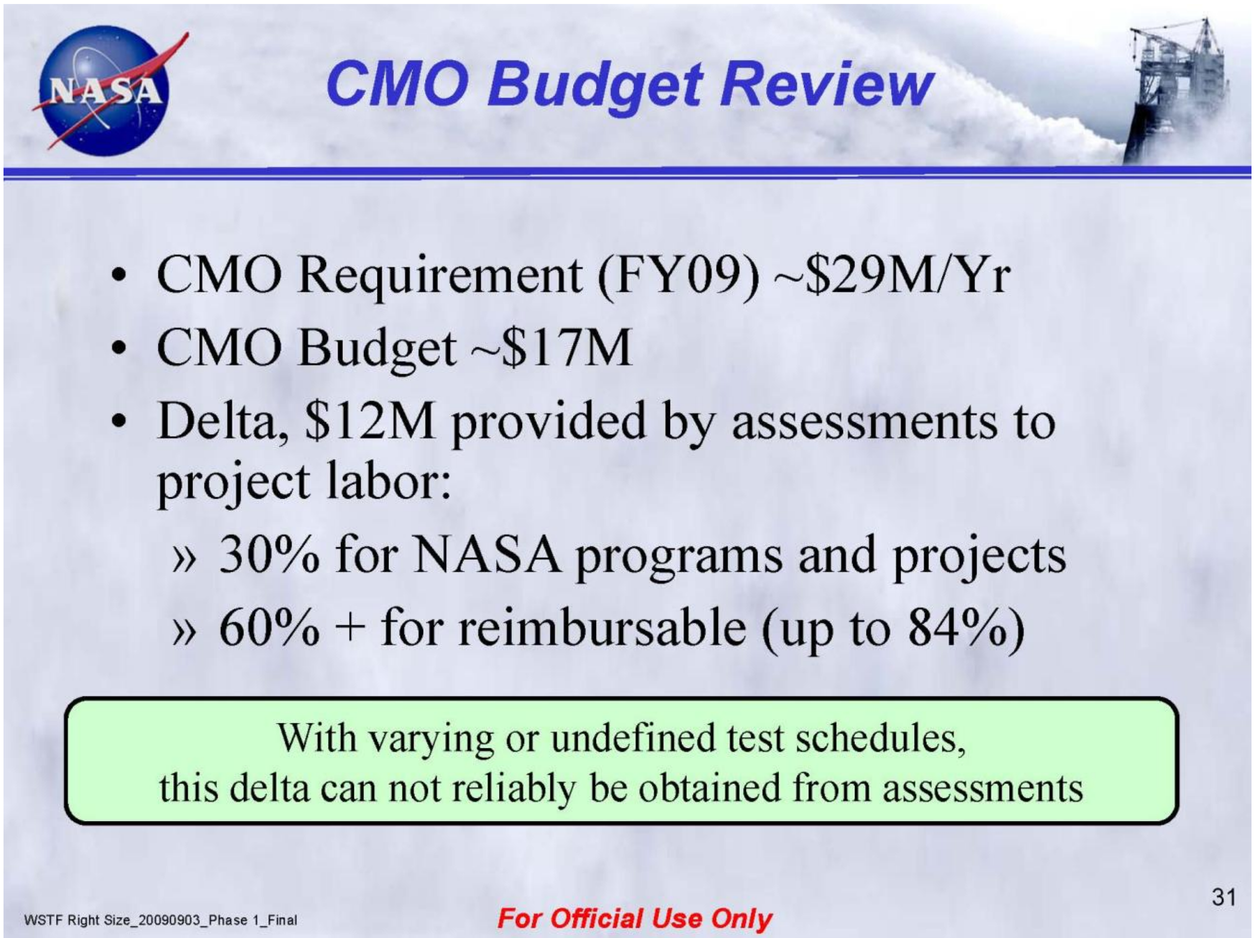
CMO Budget Review
• CMO Requirement (FY09) ~$29M/Yr
• CMO Budget ~$17M
• Delta, $12M provided by assessments to project labor:
» 30% for NASA programs and projects
» 60% + for reimbursable (up to 84%)
With varying or undefined test schedules, this delta can not reliably be obtained from assessments
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Center Maintenance and Operations

- The functions supported by CMO funding can be broken into two categories
  - » Independent- Does not vary with number of test programs or site population
  - » Dependent- Does vary with number of test programs or site population

INDEPENDENT	DEPENDENT
REAL PROPERTY	IT
FACILITY MAINTENANCE	SECRETARIES
RADIOS AND PAGING	LOGISITICS
COMPLIANCE, REPORTING, PERMITTING	OFFICE SUPPLIES & COPY PAPER
PROTECTIVE SERVICES	VEHICLE MANAGEMENT
EMERGENCY NOTIFICATION	FACILITY MODS, REHAB, REPAIR
MANAGEMENT SYSTEMS	UTILITES
	CUSTODIAL
	SAFETY & MISSION ASSURANCE
	KEYSTONE (worker safety org)
	TRAINING
	PVS
	GENERAL MANAGEMENT

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CMO Budget Summary

FY	Total In-Guide		Meet Commitments	
	Funding (K)	WYE	Cost (K) (delta In-guide)	WYE (delta)
FY10	$17,331	113	$29,239	187
			($11,908)	(74)
FY11	$17,269	113	$27,129	181
			($9,860)	(68)
FY12	$17,331	113	$27,484	171
			($10,153)	(58)
FY13	$17,639	116	$28,308	171
			($10,669)	(55)
FY14	$17,907	119	$29,055	171
			($11,148)	(52)
FY15	$18,220	121	$29,846	171
			($11,626)	(50)
6 Yr Total	$105,697		$171,061	
			($65,364)	

- 3% Inflation included

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M to $4M / yr.

TDRS ground station not included

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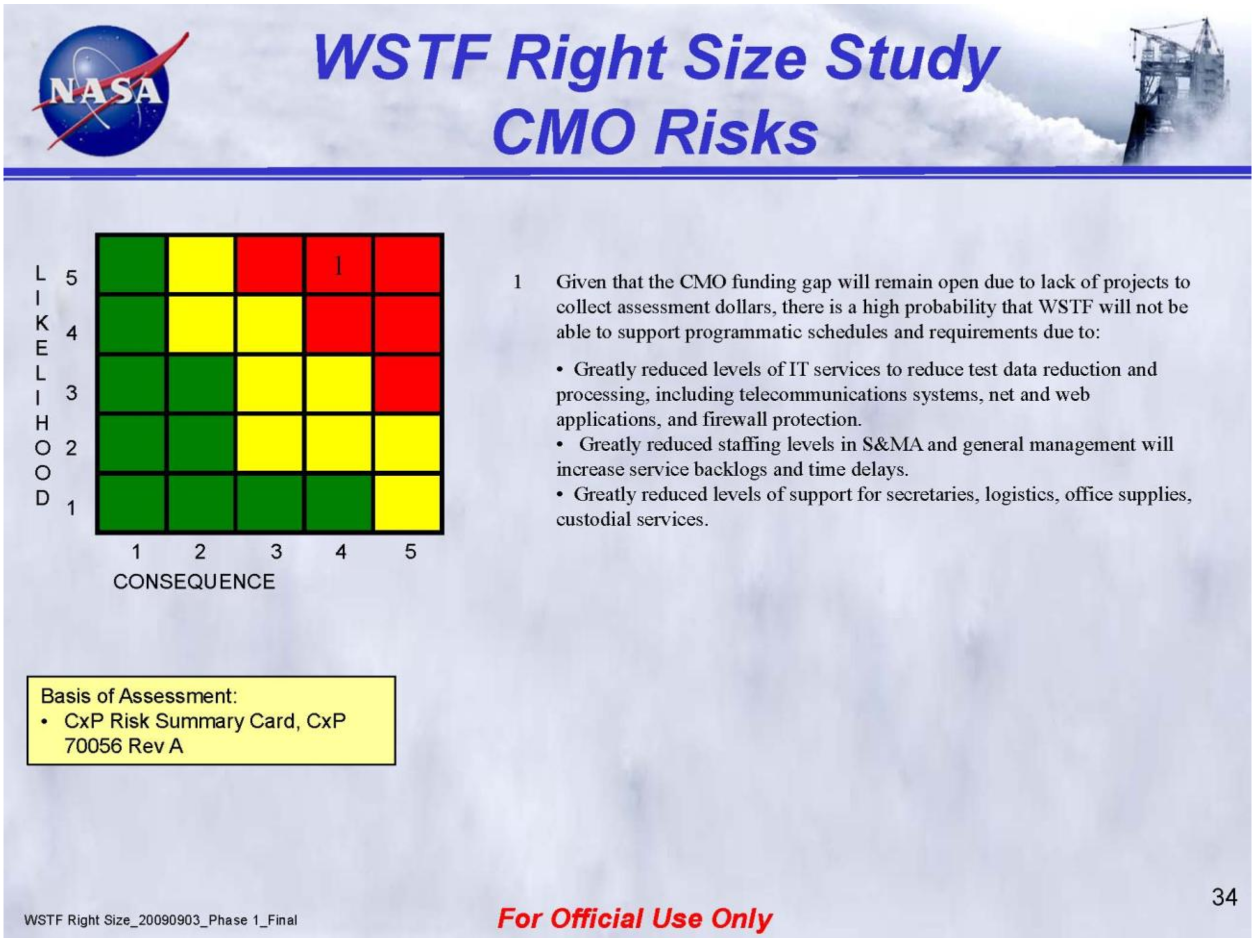
WSTF Right Size Study
CMO Risks
LIKELIHOOD
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CONSEQUENCE
1
1 Given that the CMO funding gap will remain open due to lack of projects to collect assessment dollars, there is a high probability that WSTF will not be able to support programmatic schedules and requirements due to:
• Greatly reduced levels of IT services to reduce test data reduction and processing, including telecommunications systems, net and web applications, and firewall protection.
• Greatly reduced staffing levels in S&MA and general management will increase service backlogs and time delays.
• Greatly reduced levels of support for secretaries, logistics, office supplies, custodial services.
Basis of Assessment:
• CxP Risk Summary Card, CxP 70056 Rev A
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FTE Available For New Work

FY	Totals	
	FTE AFNW	Cost (K)
FY10	0	$0
FY11	11	$1,459
FY12	16	$2,077
FY13	22	$3,068
FY14	24	$3,434
FY15	24	$3,550
6 Yr Total		$13,588

As active testing decreases available FTE's increase

Replace WYEs with FTEs, where possible

FTE AFNW is not included in previous budget charts

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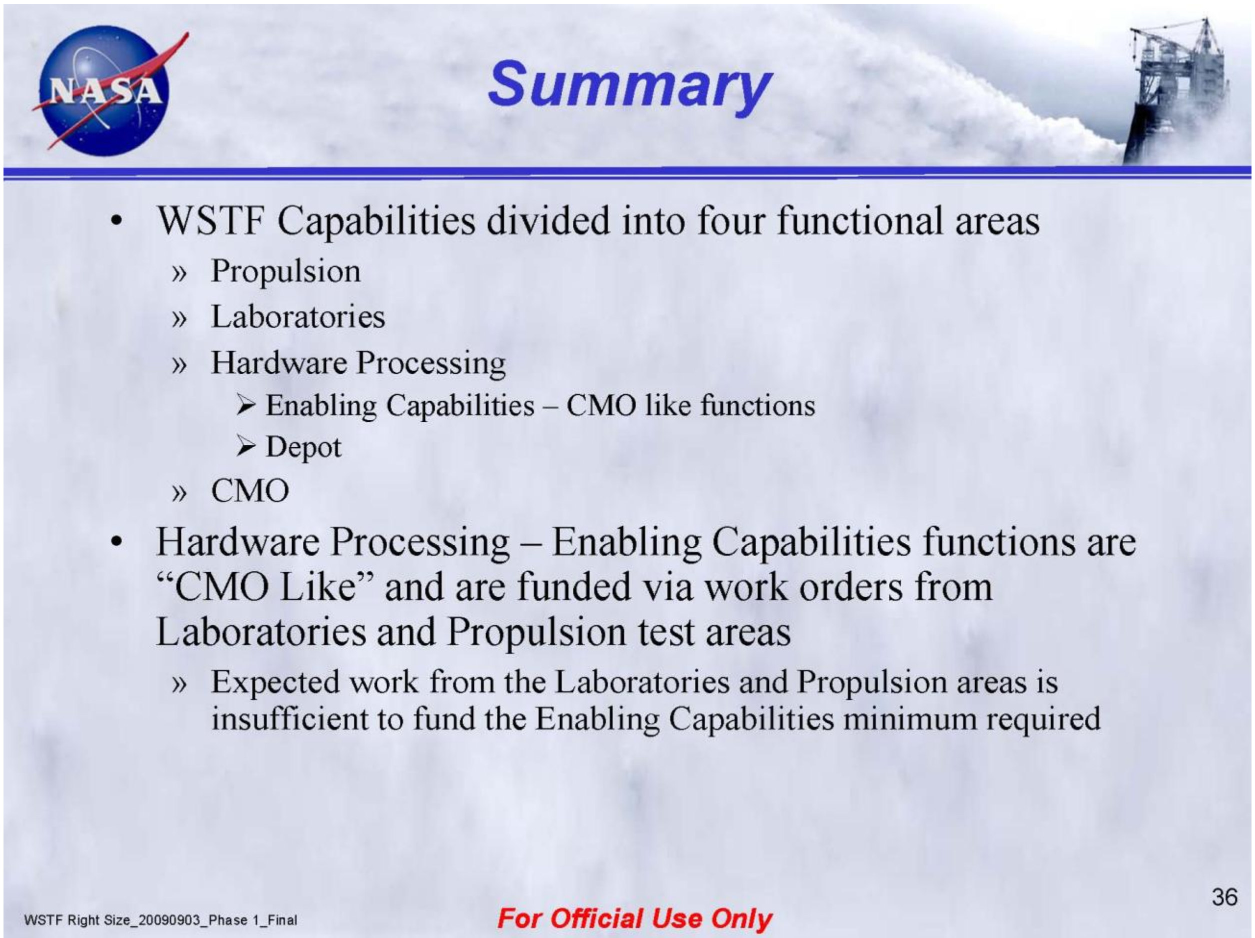

Summary
• WSTF Capabilities divided into four functional areas
» Propulsion
» Laboratories
» Hardware Processing
➢ Enabling Capabilities – CMO like functions
➢ Depot
» CMO
• Hardware Processing – Enabling Capabilities functions are "CMO Like" and are funded via work orders from Laboratories and Propulsion test areas
» Expected work from the Laboratories and Propulsion areas is insufficient to fund the Enabling Capabilities minimum required
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Summary (cont)

- By "Right Sizing" WSTF functions and removing leans against active test programs, gap for the Propulsion, Laboratories, and Hardware Processing functional areas would be minimized
  - » Propulsion "right size" would result in maintaining 3 of 9 test stands in 300 and 400 areas, 60% WYE reduction, minimum crews to maintain certifications and critical skills retention, and maintain environmental permits
  - » Laboratories "right size" would result in 20% reduction in total workforce
  - » Hardware Processing "right size" would result in > 57% reduction in total workforce – However, remaining 50% is dependent on work received from Propulsion and Laboratories ("CMO Like")
  - » First cut at the CMO "right size", based on right sizing the other functional areas, would result in a 16% - 20% reduction in FY11 – FY15 – not including increased costs due to the new Protective Services Contract
- Gap in FY10 has increased from HSCF reported $2.6M to $4.8M in Right Size Assessment
- However, with these actions, the WSTF funding shortfall remains – ranging from $4.5M to $23M per year between FY10 – FY15, including 3% inflation/yr
  - » Most significant contribution to the shortfall is CMO – ranging from $10M to $12M per year between FY10 – FY15
    - ➢ Gap can not be closed with leans against programs and projects
  - » Second greatest contribution to the shortfall is from the CMO Like Hardware Processing – Enabling Capability functional area – averaging ~ $3M per year from FY11 – FY15
- Total Gap through FY15 is $99M

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Core Capabilities Budget Summary

FY	Propulsion		Laboratories		Hardware Processing		CMO		Total	
	Total Cost delta budget	WYE	Total Cost delta budget	WYE	Total Cost delta budget	WYE	Total Cost delta budget	WYE	Total Cost delta budget	WYE
FY10	$4,554 $210	36	$9,943 $692	70	$6,398 $183	61	$29,239 ($11,908)	187	$49,864 ($10,553)	354
FY11	$4,774 ($56)	37	$8,372 ($1,729)	71	$5,184 ($1,655)	43	$27,129 ($9,860)	181	$45,318 ($13,159)	332
FY12	$5,632 ($860)	43	$8,374 ($2,920)	61	$5,339 ($2,519)	43	$27,484 ($10,153)	171	$46,684 ($16,307)	318
FY13	$6,247 ($1,825)	47	$8,644 ($2,987)	61	$5,498 ($2,844)	43	$28,308 ($10,669)	171	$48,547 ($18,175)	322
FY14	$6,651 ($2,229)	49	$8,744 ($3,189)	60	$5,663 ($3,145)	43	$29,055 ($11,148)	171	$49,959 ($19,557)	323
FY15	$6,802 ($2,380)	49	$8,909 ($3,337)	59	$5,834 ($3,371)	43	$29,846 ($11,626)	171	$51,232 ($20,555)	322
6 Yr Total	$34,660 ($7,140)		$52,986 ($13,469)		$33,916 ($13,351)		$171,061 ($65,364)		$292,623 ($99,325)	

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M - $4M per yr.

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Recommendations FY 2010 and FY 2011

- FY10 – Fund WSTF gap ($4.8M) through 50/50 SOMD and ESMD funds or Agency funds
  - » Utilizes current funding model – assessments ($6.0M)
- FY11 – Remove CMO Assessment on NASA Programs and Projects
  - » Update the business model for commercial activities
    - ➢ Current model has up to a 84% assessment (60%WSTF on Labor + 15% JSC on Total)
    - ➢ Using current customers and expected work, assessments would be $1.7M in FY11 and $1.4M in FY12 – FY15
- FY11 – Fund WSTF gap ($13.1M, with reduction for assessments + AFNW) through realignment of funds
  - » Use the Assessment dollars to offset the Laboratories gap
  - » Fund CMO gap ($9.9M) + Hardware Processing ($1.6) through 50/50 SOMD and ESMD funds or Agency funds - $11.5M
  - » Fund Propulsion gap through RPT - $0.1M
  - » Fund AFNW ($1.5M) through realignment with intent to reduce through transfer of functions from contractor responsibilities to government responsibilities
- Re-evaluate FY 12 – 15 to gather knowledge about future needs and refine inputs for submission into FY12 PPBE

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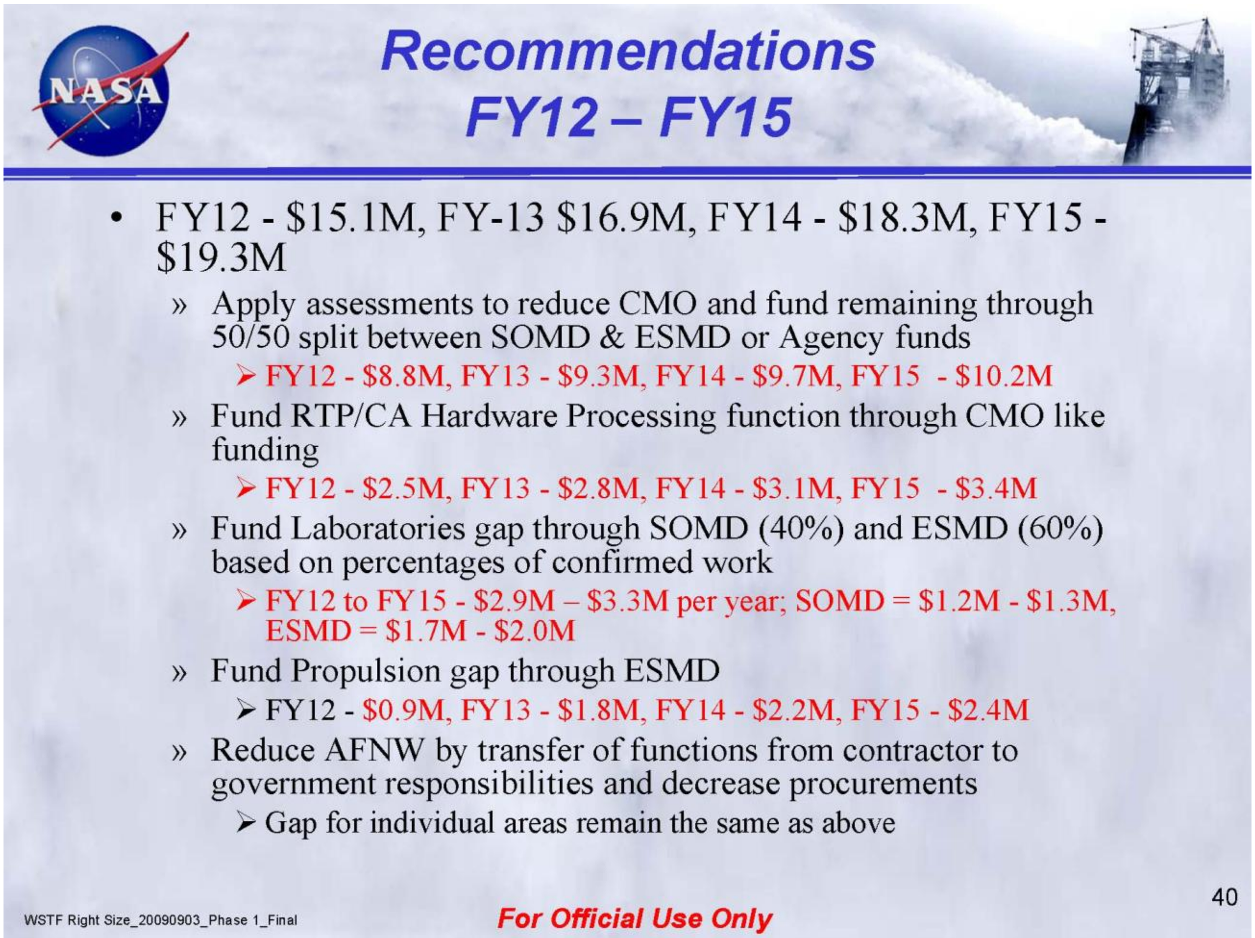
Recommendations
FY12 – FY15
• FY12 - $15.1M, FY-13 $16.9M, FY14 - $18.3M, FY15 - $19.3M
» Apply assessments to reduce CMO and fund remaining through 50/50 split between SOMD & ESMD or Agency funds
➢ FY12 - $8.8M, FY13 - $9.3M, FY14 - $9.7M, FY15 - $10.2M
» Fund RTP/CA Hardware Processing function through CMO like funding
➢ FY12 - $2.5M, FY13 - $2.8M, FY14 - $3.1M, FY15 - $3.4M
» Fund Laboratories gap through SOMD (40%) and ESMD (60%) based on percentages of confirmed work
➢ FY12 to FY15 - $2.9M – $3.3M per year; SOMD = $1.2M - $1.3M, ESMD = $1.7M - $2.0M
» Fund Propulsion gap through ESMD
➢ FY12 - $0.9M, FY13 - $1.8M, FY14 - $2.2M, FY15 - $2.4M
» Reduce AFNW by transfer of functions from contractor to government responsibilities and decrease procurements
➢ Gap for individual areas remain the same as above
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Recommended Funding Profile

$K	FY10	FY11	FY12	FY13	FY14	FY15	10-15 Total
SOMD	$2,407	$6,534	$6,816	$7,263	$7,734	$8,145	$38,897
ESMD	$2,407	$6,534	$8,260	$9,685	$10,600	$11,192	$48,678
Total Funding	$4,813	$13,068	$15,075	$16,948	$18,334	$19,337	$87,575

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Appendix C. White Sands Test Facility "Right Size" - Phase 1 Update and Phase II Outbrief, dated December 8, 2009

Topics

- Task
- Executive Summary
- Phase I Update and Implementation Approach Provided By WSTF
- Phase II
  - Approach
  - Team Members
  - Schedule
  - Recommendations
  - Budget Impact
  - Summary
- Phase I and Phase II Combined Summary
- Closed Session – Procurement Sensitive
- Recommendations

Task

- Conduct an assessment of the WSTF core capabilities to identify options for forward plans that will correctly size the WSTF capability for the work levels expected in the years after the last Space Shuttle Mission. Plans taken into account include CxP and other NASA program DDT&E requirements, schedules, and utilization plans.
  - The assessment shall include
    - ✓ A description of existing WSTF capabilities (Phase I)
    - ✓ A review of future NASA program/project requirements for facility's capabilities over the FY11-15 (Phase I)
    - ✓ A recommendation for the sizing and funding each capability and the overall WSTF to meet known NASA requirements. (Phase I, updated with Phase II)
- Additional requirements:
  - Assess technical capabilities that exist at WSTF and other NASA sites and recommend closure, consolidations or relocations in order to lower NASA costs. (Phase II)
  - ✓ Provide recommendations/projections on reimbursable work and the total annual WSTF resources that could be used. (Phase I)
- Product is an executable plan with projected costs/savings, schedule and appropriate options to sustain a right sized WSTF, post Shuttle.

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Executive Summary

- Phase I
  - WSTF continues to seek ways to reduce operating expenses
  - Some additional reductions have been identified in each of the Core Capabilities
  - Minimal reductions in CMO
  - Efforts underway to implement decisions from Phase I
- Phase II
  - Excellent participation and cooperation from Center representatives
  - Over 80 items reviewed for consolidation, transfer or assignment
- Combined Phase I and Phase II efforts, if implemented and realized, could offset the WSTF gap nearly $45M (nearly ½) through FY2015
- Dollar's transferred first applied to the Core Capability and any excess then applied to reducing overall WSTF gap
  - Focuses first on maintenance of core capabilities and critical skills

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Bottom Line Up Front

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

$M	FY09	FY10	FY11	FY12	FY13	FY14	FY15	10-15 Total
March 2008 HSCF II Gap	$10,700.0	$0.0	$24,200.0	$29,700.0	$29,700.0	$33,000.0		$116,600.0
April 2009 HSCF III Gap	$0.0	$2,600.0	$14,900.0	$23,200.0	$27,600.0	$31,200.0	$32,300.0	$131,800.0
Sept 2009 Right Size Gap		$4,813.0	$13,068.0	$17,152.0	$20,016.0	$21,768.0	$22,887.0	$99,704.0
Right Size Totals		$66,040	$53,297	$50,191	$49,982	$49,496	$50,743	$318,118
Total Available Funding		$53,828	$42,435	$36,710	$34,731	$31,744	$31,925	$231,373
Right Size Gap without assessments		$12,212	$10,862	$13,481	$15,251	$17,752	$18,818	$88,376
Program Assessments		$10,700	$2,400	$2,400	$2,400	$2,400	$2,400	$22,700
Right Size Gap with assessments		$1,512	$8,462	$11,081	$12,851	$15,352	$16,418	$65,676
Available For New Work (AFNW)		$0.0	$1,459.0	$2,077.0	$3,068.0	$3,434.0	$3,550.0	$13,588.0
Total Gap (December 2009)		**$1,512**	**$9,921**	**$13,158**	**$15,919**	**$18,786**	**$19,968**	**$79,264**
Potential Phase II Funding		$2,810	$5,879	$5,647	$3,684	$3,317	$3,628	$24,964
Gap with potential Phase II Funding		$1,298	$4,042	$7,511	$12,235	$15,469	$16,340	$54,300
Gap w/Phase II and Excluding AFNW		$1,298	$2,583	$5,434	$9,167	$12,035	$12,790	$40,711

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WSTF Core Capabilities – Budget Summary

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

Black (positive) gaps are assumed to reduce the overall WSTF gap

CMO costs in FY12-15 are still under evaluation and are expected to decrease, affecting gap values

FY	Propulsion			Laboratories			Hardware Processing			CMO		Total		
	Total Cost	Gap	Gap Phase II	Total Cost	Gap	Gap Phase II	Total Cost	Gap	Gap Phase II	Total Cost	Gap	Total Cost	Gap*	Gap Phase II*
FY10	$17,453	$0	$228	$11,747	($1,022)	($172)	$8,640	$10	$1,742	$28,200	($500)	$66,040	($1,512)	$1298
FY11	$13,840	$1,344	$2,378	$7,932	($1,289)	$169	$4,396	($1,057)	$2,330	$27,129	($7,460)	$53,297	($8,462)	($2,583)
FY12	$10,274	$750	$1,454	$7,934	($2,370)	($311)	$4,499	($1,708)	$1,176	$27,484	($7,753)	$50,191	($11,081)	($5, 434)
FY13	$8,888	($120)	$703	$8,204	($2,547)	($435)	$4,582	($1,915)	($1,166)	$28,308	($8,269)	$49,982	($12,851)	($9,167)
FY14	$7,368	($1,600)	($713)	$8,304	($2,639)	($473)	$4,769	($2,365)	($2,101)	$29,055	($8,748)	$49,496	($15,352)	($12,035)
FY15	$7,568	($1,800)	($848)	$8,469	($2,787)	($565)	$4,860	($2,605)	($2,151)	$29,846	($9,226)	$50,743	($16,418)	($12,790)
6 Yr Total	$65,391	($1,426)	$3,202	$52,590	($12,654)	($1,787)	$31,746	($9,640)	($170)	$170,022	($41,956)	$319,749	($65,676)	($40,711)

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M - $4M per yr.

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Phase I Update

Phase I Actions

1. Implement the proposed reductions and test facility state change recommendations from the "Right Size" study.
2. Continue to evaluate the WSTF CMO problem and determine mitigation options.
3. Identify non-value added, costly, unfunded mandates for possible assistance in relieving requirements.
4. Evaluate whether NASA funding is subsidizing reimbursable test customers.
5. Evaluate future reimbursable work WSTF will be able to obtain through 2015 to offset NASA core capabilities costs.
6. Evaluate closing laboratory and enabling capabilities areas, if there is no work.
7. Validate the ready to produce costs associated with laboratory core capabilities.
8. Re-evaluate all core capability costs and staffing, to identify areas of further reduction or consolidation.

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Implement the proposed staffing reductions and test facility state changes as identified in the Right Size study (Actions 1, 6, 7, 8)

- Develop a plan for reducing test stand readiness levels and the size of the contractor test team to meet budgets as presented in the Right Size presentation package. (1)
  - The following charts describe the "Right Size" Plans.
- Investigate closing areas of Labs and Enabling Capabilities functions when work load is reduced. (6)
  - Workload is reduced somewhat, but all capabilities are still required. This will not allow reduction in facility footprint. Issue is not the lack of work for the areas, but lack of ready to produce funding due to shuttle retirement.
- Validate the Labs Core capability Ready to Produce Costs. (7)
  - These costs have been reviewed by management, again, and no further reductions were identified.
- Review core capability costs and staffing, again, for additional areas of reduction or consolidation. (8)
  - Completed. All areas were reassessed and have shown some reductions in costs and staffing. Reflected in following charts.

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General Actions / Overview

- In order to place the WSTF in the proper posture for the level of activity anticipated due to Shuttle Retirement and lack of defined future testing and to attempt to reduce the unfunded gap, the following has taken place:
  - Work with contractor team on short term fixes
    - Allow attrition to lower contractor WYE's
    - Reduce overtime
    - Implement shorter work weeks for some employees
    - Encourage the liberal use of leave
    - Increase cross training to mitigate skills loss
    - Implement staffing reductions as necessary
  - Continue to pursue additional reimbursable work
  - Develop a plan to decrease work force and Mothball facilities to fit the anticipated work load
    - Needs to be continually addressed to assess new work assignments
- Issues
  - CMO is still the main contributor to funding gap, and is the most difficult to mitigate
  - While FY 10 appears to be manageable from a funding and workforce perspective, all areas have a potential for personnel staffing reductions in FY10, due to tentative nature of some of the projected work.
  - Can only reduce to a certain level (both facilities and personnel) before core capability and critical skills impacted
  - Test stand mothballing and staffing reductions will negatively impact response times to customers.
    - 12-18 months to transition a test stand from mothball to active
    - 6-12 months to stand up test teams
- Revised data in this analysis includes cost and staffing values for test, maintenance, and core capability .
  - Version presented in September was not consistent in accounting for test costs and personnel
- Annual funding, anticipated costs and WYE projections are estimates based on today's information and will have to be reassessed as work loads change.

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Continue to evaluate the WSTF CMO problem and determine mitigation options – Action 2

- Predicted FY10 CMO shortfall nearly mitigated
  - Phase I presented a projected CMO shortfall of ~$11M, assuming no assessments and $5M shortfall assuming assessment of project funding but not maintenance funding. In reality all (labor) funding is being assessed. This has reduced the predicted CMO shortfall to $0.5M.
  - Assessments decrease labor funding available for projects and maintenance
- Further work is being done to reduce the CMO bill for FY10 and make up the remaining shortfall
  - CMO funded IDIQ task orders are being reduced 25% year over year, on both NTEC and FOSC contracts
  - NTEC and FOSC contract management asked to propose Completion Form reductions ranging from 15%-35%
    - NASA will assess risk, cost savings, timelines, and implement as appropriate
    - Requires contract change
  - NASA Facility Operations, is reviewing IDIQ Maintenance and Repair activities to determine what could be delayed, deferred, or deleted
  - Continuing to pursue additional reimbursable test customers
- Contractor staffing reductions as appropriate (attrition, RIF, and reduced hours)
  - Some reductions in effect 1st quarter FY10, more expected in 2nd quarter and beyond

FY 2010 Center Management & Operations

Requirement	$28.2M
CM&O Budget	$17.0M
Assessment Required	$11.2M
Potential Assessment	$10.7M
Delta Required	$ 0.5M

- CMO budget for FY10 is nearly met
  - Potential Issues
    - Emergency repairs
    - Mishap Investigations
    - Overruns
    - Utility Usage (Colder Winter or Hotter Summer)
    - Utility Prices (Electric rates, Natural gas, Unleaded or E-85 fuels)
    - New Requirements
    - Protective Services Contract
  - Potential Opportunities
    - Additional Reimbursable Customers
    - Additional work from other centers as part of consolidation effort
    - Realization of cost savings from current contracts

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Long Term Actions FY11 and Beyond

- Reduced CMO costs from
  - Contracts
  - Right Size implementations
    - Smaller Operation
      - Reduce I/T Seats, utilities, maintenance, etc.
    - Increased utilization
      - Phase II implementation
- Impact is still not clear and will most likely require an augmentation of CMO Budget, in FY 2011 and beyond

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CMO Budget Summary
as of 12/04/2009

Note: Red numbers indicate negative (gap) values

FY	Anticipated		Requirements	
	Funding (K)	WYE	Cost (K) (gap)	WYE
FY10	$27,700*	201	$28,200	205
			($500)	
FY11	$19,669**	143	$27,129	181
			($7,460)	
FY12	$19,731**	143	$27,484	171
			($7,753)	
FY13	$20,039**	146	$28,308	171
			($8,269)	
FY14	$20,307**	148	$29,055	171
			($8,748)	
FY15	$20,620**	150	$29,846	171
			($9,226)	

- 3% Inflation included
- * Fy10 includes assessments on all projects
- **Fy11 and beyond includes assessment only on Non-NASA reimbursable projects.
- Expect reductions in requirements FY11 and beyond due to actions previously defined

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M to $4M / yr.

TDRS ground station not included

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Action (#3)
Identify Non-Value Added, Costly, Unfunded Mandates for Possible Assistance in Relieving Requirements

- **Protective Services** (Site-wide impact) – as initially awarded will have a significant cost increase. **(Estimated cost impact to WSTF $4M annually)**
- **Increasing IT Security requirements** (indeterminate cost; details in work) Significant increase in requirements for IT security not based on smart criteria. Isolated data acquisition systems being treated/viewed as network-connected. Constant justifications detract facility personnel from focus on test capabilities. There may be other IT support costs to JSC which are not evident.- **(Estimated cost impact to WSTF varies $50K-275K annually; Total impact for FY10-FY15 is $720K)**

Action (#3)
Identify Non-Value Added, Costly, Unfunded Mandates for Possible Assistance in Relieving Requirements

- **Implementation of Calibration standard Z540.3-2006 (included in NPD8730.1C)– (Cost)**
  - WSTF currently complies to NPD 8730.1B which invoked ANSI/NCSL Z540.1-1994
  - NPD 8730.1C invokes ANSI/NCSL Z540.3-2006
  - Compliance Concerns in implementing Z540.3-2006
    - It invokes a totally new definition of Test Uncertainty Ratio (TUR)
    - Requires uncertainty budgets for every measurement (these are rigorous exercises involving complex mathematical computations and experimental formulations)
    - Requires external audits to Z540.3
    - Requires all suppliers compliant to Z540.3, if not, organization must complete the unfulfilled requirements
  - **Estimated cost impact to WSTF**
    - WSTF estimates a $250K - $300K added cost per year to comply to Z540.3 (This is calibration cost only, there would be potential additional costs related to the external audit and any corrective actions resulting from the audit.)
    - Stennis estimates a $300K - $500K increase per year (we don't currently have data from the other centers)

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Actions #4 and #5 Reimbursable Work

- Evaluate whether NASA funding is subsidizing reimbursable test customers.
  - Non-NASA reimbursable customers pay for actual costs associated with testing (per space act agreement) and are assessed 60% on contractor labor dollars spent in order to pay for WSTF city management costs. In addition, these customers pay direct CS labor and an additional JSC tax of ~15% on the total funds transferred to NASA.
  - It is not apparent that NASA WSTF is subsidizing
- Evaluate future reimbursable work WSTF will be able to obtain through 2015 to offset NASA core capabilities costs.
  - Based on history, WSTF will attract approximately $5M annually in non-NASA reimbursable work.
  - WSTF personnel continue to develop industry contacts in order to continue to obtain reimbursable test work.

Phase II

Team Members

- MSFC – Jim Reuter
- KSC – Brian Nufer
- SSC – Kern Witcher
- JSC – Mark Ferring
- GRC – Rickey Shyne
- GSFC – Gil Colon
- ARC – Carol Russo
- PAE Cost Assessment – Josh Manning
- LARC – Cynthia Lee
- JPL – none provided
- NESC – Mike Kirsch
- PAE – Ave Kludze
- CEO – Greg Robinson
- FERP – George Madzsar
- WSTF – Bob Kowalski
- PAE Cost Assessment – Charles Hunt

- Plus numerous back-ups / alternates and contributors

Phase II Approach

- Contacted each Center Director to discuss task and to obtain a Center POC
- Each Center POC requested to review functions, capabilities, and activities that could be candidates for transfer / move to or from WSTF – open and free discussion
  - Candidates fall into three categories – Duplicative, Similar, one to two off of
  - Candidates assessed on two categories – Applicability (1-3, low to high) and Difficulty (1-3, hard to easy) from a Center and WSTF perspective
  - Each item given a score based on assessment
  - Items receiving a score of 4 or greater by WSTF passed to PA&E for budgetary assessment and impacts (round 1)
  - Items inconsistently assessed by WSTF and Centers identified for additional discussions
  - Site visits to resolve differences and gain further understanding of requirements
- Candidate functions recommended for transfer must be a total transfer – function, testing, and **funding**

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Phase II Candidate Summary

- Over 80 items reviewed as candidates
  - All items ranked for *Applicability* and *Difficulty*
  - 44 receiving a cumulative assessment $\geq$ 4
- Large test stands and other items that would require significant CoF activities or increase to WSTF supporting infrastructure removed from consideration
- Action to team members to work with Agency calibration and cleaning working groups to identify niche markets / areas of expertise that would be suitable to have WSTF do for all Centers
  - Transfer of entire "lab" functions from Centers to WSTF removed from consideration
- All Centers reviewing outsourced functions to identify work that can be provided by WSTF vs outside vendor
  - Manufacturing, Cleaning, Calibration, …

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Ground Rules & Assumptions

Office of Program Analysis and Evaluation

- All costs are represented in Real Year 1,000's dollars
- **Cost numbers represent the net impact to WSTF**
  - Negative numbers have a positive impact to WSTF
  - Savings at a given Center due to consolidation is considered to be fungible to WSTF
- Costs captured through 2015
  - Not applying discount rates via OMB Circular A-94
- Basis-of-Estimate (BOE) provided by Centers
  - Center inflation rates utilized
- Transition costs developed parametrically
  - Transportation costs provided by HQ Logistics Office
  - Labor estimates provided by PA&E ROM
- ODC and consumables considered a wash for any trade
- FTEs located at "From" Center assumed to be available for new work
  - Not accounting for placement alternatives such as FTE transfer costs
  - Savings equal to annual Agency attrition rate except for first year
- No restrictions assumed for WYE costs associated with "From" Center
  - Unless stated otherwise in the BOE
- All estimates are deterministic and not risk adjusted (accounting for unknown-unknowns)
- Candidates divided into three categories
  - Niche and Overflow Work – Work to be performed at WSTF as needed
  - Testing and Shuttle Transition and Retirement – Actual testing or decon work that can be assigned at any time
  - Duplication – Capability is a duplication to facilities / work already being performed as part of WSTF Core Capabilities

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Example
MSFC MCRF Data Sheet

MSFC	Capability =	MCRF							BLDG 4623
Description	BOE	FY10	FY11	FY12	FY13	FY14	FY15	Total	Comments/Notes
O&M Savings	Center provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Not available by Test
Divestment Costs		$ -	$ -	$ -	$ -	$ -	$ -	$ -	Assumed no divestment costs due to additional test facilities located in bldg 4623
FTE ($) Savings	Center provided	$ -	$ (15)	$ (30)	$ (45)	$ (61)	$ (78)	$ (229)	
WYE ($) Savings	Center provided	$ (647)	$ (669)	$ (691)	$ (715)	$ (739)	$ (764)	$ (4,225)	
Deferred Maintenance (DM)									N/A due to metrics being kept at "facility" level
	"From" Total Cost:	**$ (647)**	**$ (683)**	**$ (721)**	**$ (760)**	**$ (800)**	**$ (842)**	**$ (4,453)**	
WSTF									**BLDG 800**
Description	BOE	FY10	FY11	FY12	FY13	FY14	FY15	Total	Comments/Notes
O&M Increases	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Assume minimal. No delta assumed in ODC
Investment Costs	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	As stated, no facility mods needed
FTE ($) Increases	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	As stated, no additional personnel need
WYE ($) Increases	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	As stated, no additional personnel need
Deferred Maintenance (DM)									N/A due to metrics being kept at "facility" level
	"To" Total Cost:	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	
Description	BOE	FY10	FY11	FY12	FY13	FY14	FY15	Total	Comments/Notes
Transition Costs	HQ Logistics ROM	$ 7	$ -	$ -	$ -	$ -	$ -	$ 7	Packaging and transportation (includes labor)
	Total Cost Delta:	**$ (640)**	**$ (683)**	**$ (721)**	**$ (760)**	**$ (800)**	**$ (842)**	**$ (4,446)**	

Notes:

WSTF indicated that no equipment would need to be moved. Possible additional savings if equipment was sold.

WSTF is a testing laboratory and this work is in our core. MSFC is historically a materials technology and development laboratory. WSTF's position is that this work (including all equipment and any potentially available maintenance funding) should be relocated to WSTF.

The Building will continue to be utilized for the following reasons. 1.) Building 4623 contains MSFC's Environmental Gas Lab (EGL) – required to sample and test centerwide propellants and pressurants distribution systems, clean rooms, and flow benches; 2.) Due to the fixed-price nature of MSFC's facilities base operations contract, closing this building would not save any of the Facilities O&M costs because the size of the building is significantly less than the size threshold required for a contract cost adjustment. 3.) Since the Utility costs are generally low (about $50K/year), it is more cost effective for MSFC to maintain the EGL at this location rather than incur the high cost and disruptions associated with relocating the EGL.

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Example
MSFC: MCRF (total)

- **Description**:
  - Materials Combustion Research Facility (MCRF)
  - Additional test facilities located in 4623 not listed below include ignition delay testing; impact/ignition testing of nitrous oxide; hydrogen peroxide materials compatibility testing; accelerated aging of materials in high-concentration hydrogen peroxide testing. These facilities generally offer unique capabilities and are used on an as-needed basis. There is currently a Space Act Agreement in place for work using the impact/ignition testing of nitrous oxide facility.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
MCRF	$ (640)	$ (683)	$ (721)	$ (760)	$ (800)	$ (842)	$ (4,446)

- **Type: Duplicated Capabilities**
  - Core Capabilities: Ambient Temperature Promoted Combustion Test, Elevated Temperature Promoted Combustion Test, Flight Materials Flammability Test, Materials Toxicity Testing for Astronaut Safety, Hypergolic Materials and Component Testing, Mechanical Impact Testing of Materials in Oxygen, Oxygen Compatibility Assessments, Thermal Vacuum Outgassing Testing
- **Cost Drivers:**
  - Cost savings due to the potential reduction of 8 WYE and available for new work for 2.5 FTE
  - Transition costs are minimal (WSTF stated that no equipment transfer necessary)
  - No additional personnel needed at WSTF
- **Notes:**
  - Transportation costs captured by HQ Logistics Office
  - The Building will continue to be utilized for the following reasons
    - Contains MSFC's Environmental Gas Lab (EGL) -- required to sample and test centerwide propellants and pressurants distribution systems, clean rooms, and flow benches
    - Due to the fixed-price nature of MSFC's facilities base operations contract, closing this building would not save any of the Facilities O&M costs because the size of the building is significantly less than the size threshold required for a contract cost adjustment
    - Since the Utility costs are generally low (about $50K/year), it is more cost effective for MSFC to maintain the EGL at this location rather than incur the high cost and disruptions associated with relocating the EGL.

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Example
GRC Thermal Vac Data Sheet

GRC	Capability =	Thermal Vac Propulsion Testing							Building 147
Description	BOE	FY10	FY11	FY12	FY13	FY14	FY15	Total	Comments/Notes
O&M Savings		$ -	$ -	$ -	$ -	$ -	$ -	$ -	None as facility is new and will be reused
Divestment Costs		$ -	$ -	$ -	$ -	$ -	$ -	$ -	
FTE ($) Savings	Center provided	$ -	$ -	$ -	$ (20)	$ (41)	$ (62)	$ (123)	Utilized FY12 FTE
WYE ($) Savings	Center provided	$ -	$ -	$ (445)	$ (459)	$ (472)	$ (487)	$ (1,863)	Utilized FY12 WYE
Deferred Maintenance (DM)									N/A
	"From" Total Cost:	**$ -**	**$ -**	**$ (445)**	**$ (479)**	**$ (514)**	**$ (548)**	**$ (1,986)**	
WSTF									**TS 401, TS 403 or TS405.**
Description	BOE	FY10	FY11	FY12	FY13	FY14	FY15	Total	Comments/Notes
O&M Increases		$ -	$ -	$ -	$ 30	$ 31	$ 32	$ 93	O&M increase for additional propellant tanks
Investment Costs	WSTF provided	$ -	$ -	$ 750	$ -	$ -	$ -	$ 750	See notes
FTE ($) Increases	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	No additional workforce
WYE ($) Increases	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	No additional workforce
Deferred Maintenance (DM)									N/A
	"To" Total Cost:	**$ -**	**$ -**	**$ 750**	**$ 30**	**$ 31**	**$ 32**	**$ 843**	
Description	BOE	FY10	FY11	FY12	FY13	FY14	FY15	Total	Comments/Notes
Transition Costs	WSTF provided	$ -	$ -	$ -	$ -	$ -	$ -	$ -	Skids could be transferred (see notes)
	Total Cost Delta:	**$ -**	**$ -**	**$ 305**	**$ (449)**	**$ (483)**	**$ (517)**	**$ (1,144)**	

Notes

WSTF Investment Costs: None for TS 401. Propellant run tank upgrades for non-hypergolic propellants at TS403 and 405 would be required. Estimated cost ~$750K. Propellant skids from GRC could be transferred to WSTF instead of procuring new systems. Estimated transportation $5-10K

GRC Comments: Consolidation could occur in FY2012. ETDP PCAD task aggreements contain test commitments through FY2011. To move the current PCAD tests to WSTF would add a least an additional $4M cost and 2 year delay to GRC PCAD project.

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Example
GRC: Thermal Vac Propulsion Testing

- **Description**: Chemical Rocket Engine Testing to Simulated Altitude of 120,000 ft. Up to 2000 pounds thrust

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Thermal Vac Propulsion Testing	$ -	$ -	$ 305	$ (449)	$ (483)	$ (517)	$ (1,144)

- **Type: Duplicated Capabilities**
- **Cost Drivers:**
  - No facility O&M savings as facility will continue to be utilized
  - Significant savings due to reduced workforce
  - Investment in propellant run tank upgrades for non-hypergolic propellants at TS403 and 405 would be required.
  - Storage of existing equipment at GRC not costed
- **Notes:**
  - **This capability is currently under review**
    - Estimated impact to WSTF needs to be evaluated to quantify schedule and cost impacts
  - GRC Notes: ETDP PCAD task agreements contain test commitments through FY2011. To move the current PCAD tests to WSTF would add a least an additional $4M cost and 2 year delay to GRC PCAD project.
  - Propellant skids from GRC could be transferred to WSTF instead of procuring new systems

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Summary of Phase II Candidates

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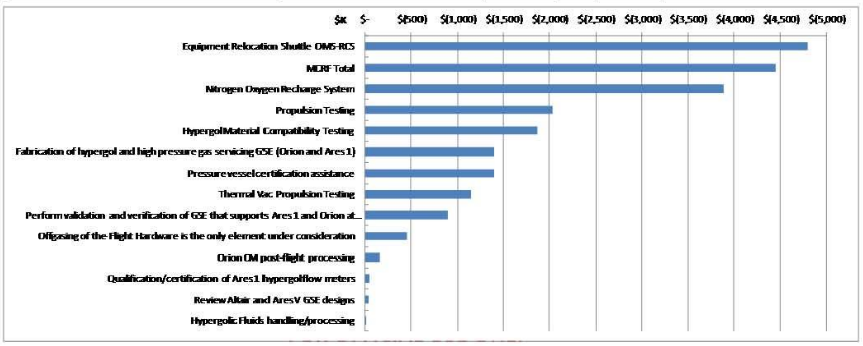
Type	All values in real year 1000's dollars	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
	GRC	$ (179)	$ (313)	$ (37)	$ (820)	$ (882)	$ (946)	$ (3,178)
D	Propulsion Testing	$ (179)	$ (313)	$ (342)	$ (371)	$ (400)	$ (430)	$ (2,034)
D	Thermal Vac Propulsion Testing	$ -	$ -	$ 305	$ (449)	$ (483)	$ (517)	$ (1,144)
	JSC	$ (210)	$ (423)	$ (775)	$ (978)	$ (981)	$ (984)	$ (4,351)
T	Nitrogen Oxygen Recharge System	$ (140)	$ (350)	$ (700)	$ (900)	$ (900)	$ (900)	$ (3,890)
D	Offgasing of the Flight Hardware is the only element under consideration	$ (70)	$ (73)	$ (75)	$ (78)	$ (81)	$ (84)	$ (461)
	KSC	$ (1,573)	$ (4,023)	$ (3,187)	$ (849)	$ (403)	$ (581)	$ (10,617)
T	Equipment Relocation Shuttle OMS-RCS	$ -	$ (2,872)	$ (1,929)	$ -	$ -	$ -	$ (4,801)
D	Hypergol Material Compatibility Testing	$ -	$ (352)	$ (363)	$ (374)	$ (385)	$ (396)	$ (1,870)
N	Fabrication of hypergol and high pressure gas servicing GSE (Orion and Ares 1)	$ (1,071)	$ (333)	$ -	$ -	$ -	$ -	$ (1,404)
N	Pressure vessel certification assistance	$ (453)	$ (467)	$ (481)	$ -	$ -	$ -	$ (1,400)
N	Perform validation and verification of GSE that supports Ares 1 and Orion at WSTF	$ -	$ -	$ (415)	$ (476)	$ -	$ -	$ (890)
T	Orion CM post-flight processing	$ -	$ -	$ -	$ -	$ -	$ (166)	$ (166)
N	Qualification/certification of Ares 1 hypergol flow meters	$ (49)	$ -	$ -	$ -	$ -	$ -	$ (49)
N	Review Altair and Ares V GSE designs	$ -	$ -	$ -	$ -	$ (18)	$ (19)	$ (37)
	MSFC	$ (640)	$ (683)	$ (721)	$ (760)	$ (800)	$ (842)	$ (4,446)
D	MCRF Total	$ (640)	$ (683)	$ (721)	$ (760)	$ (800)	$ (842)	$ (4,446)
	SSC	$ -	$ (1)	$ (2)	$ (3)	$ (4)	$ (5)	$ (14)
N	Hypergolic Fluids handling/processing	$ -	$ (1)	$ (2)	$ (3)	$ (4)	$ (5)	$ (14)
	Grand Total	$ (2,602)	$ (5,443)	$ (4,723)	$ (3,410)	$ (3,070)	$ (3,358)	$ (22,606)

TYPES: T- Test Assignments and Shuttle Transition & Retirement | N- Niche Work and Overflow Requirements | D - Duplicated Capabilities



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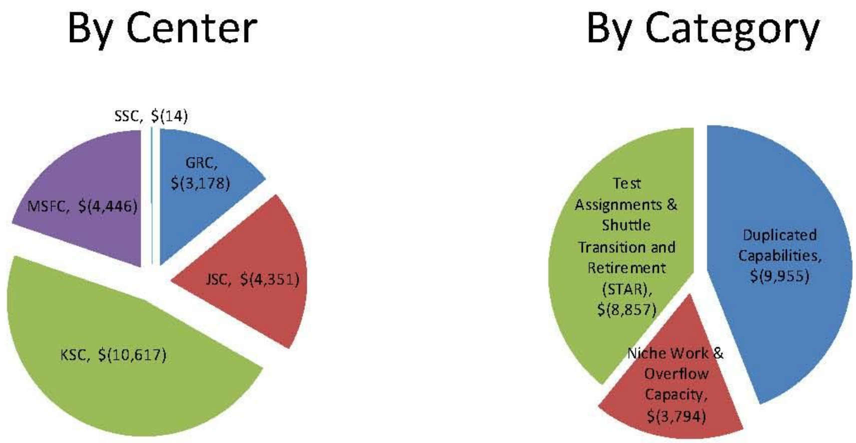
Capabilities Breakout



All costs are represented in Real Year 1,000's dollars

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Core Competencies at all NASA Centers "Niche Work / Overflow Capacities"

Office of Program Analysis and Evaluation

- Each Center has the following core competencies:
  - Gas and Materials Analysis
  - Calibration
  - Fabrication
  - Machining
  - Component Processing
  - Environmental Monitoring
- These capabilities must be maintained at each Center
- Not recommended for consolidation
- Focus on potential niche and overflow capacity work for WSTF
- **These capabilities were not costed as part of this study**
  - Action to Agency level Working Groups (Calibration, Metrology, Pressure Systems ...) to identify niche markets / work functions that could be performed at WSTF

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Marshall Space Flight Center (MSFC)

Center Contact: Jim Reuter

Office of Program Analysis and Evaluation

- **Test Assignments & Shuttle Transition and Retirement**
  - Hypervelocity Impact Testing
    - $0 current impact, MSFC / WSTF partner to develop new Exploding Wire Gun for operations at WSTF
  - Ares V Development
    - No PPBE $'s ID'd
  - Ares I Upper Stage Composite Overwrap tank testing
    - No PPBE $'s ID'd
  - Ares I US RoCS & ReCS hydrazine component compatibility qual testing
    - Desired task to be done at WSTF, No PPBE $'s ID'd
  - Ares I US material hydrazine compatibility & adiabatic compression detonation testing
    - Desired task to be done at WSTF, No PPBE $'s ID'd
  - Ares I Upper Stage RoCS & ReCS Subsystem Qual Hot Fire Testing (HFTA)
    - Baselined at WSTF – captured in Phase I Assessment
  - Ares I Upper Stage RoCS & ReCS Thruster Hot Fire Qual
    - See detailed sheet
- **Duplicated Capabilities**
  - Materials Combustion Research Facility (MCRF)
    - See detailed sheet

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MSFC: Ares I Upper Stage RoCS & ReCS Thruster Hot Fire Qual

- **Description**:
  - Aerojet thruster testing

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Ares I Upper Stage RoCS & ReCS Thruster Hot Fire Qual	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- **Type: Test Assignments & Shuttle Transition and Retirement**

- **Cost Drivers:**
  - Not costed

- **Notes:**
  - This item presents a similar issue as the Orion Crew Module and Service Module thruster testing being performed at Aerojet
  - Testing is part of the deliverable in the Boeing Upper Stage Contract
  - Test requirements have not been fully scoped so Boeing has not costed actual testing
  - Task assigned to CxP FCB and Upper Stage Project to perform trades and impacts of performing testing at WSTF
  - Proceed with same criteria established in PDM 10 OCE 2, concurred with by ESMD, for Orion SM / CM testing at Aerojet
  - Ares Project considers it to be very highly undesirable to take thruster test contractual responsibility away from Boeing Prime and Aerojet supplier
  - Likely significant cost increase per Upper Stage Project

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MSFC: MCRF (total)

- **Description**:
  - Materials Combustion Research Facility (MCRF)
  - Additional test facilities located in 4623 not listed below include ignition delay testing; impact/ignition testing of nitrous oxide; hydrogen peroxide materials compatibility testing; accelerated aging of materials in high-concentration hydrogen peroxide testing. These facilities generally offer unique capabilities and are used on an as-needed basis. There is currently a Space Act Agreement in place for work using the impact/ignition testing of nitrous oxide facility.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
MCRF	$ (640)	$ (683)	$ (721)	$ (760)	$ (800)	$ (842)	$ (4,446)

- **Type: Duplicated Capabilities**
  - Core Capabilities: Ambient Temperature Promoted Combustion Test, Elevated Temperature Promoted Combustion Test, Flight Materials Flammability Test, Materials Toxicity Testing for Astronaut Safety, Hypergolic Materials and Component Testing, Mechanical Impact Testing of Materials in Oxygen, Oxygen Compatibility Assessments, Thermal Vacuum Outgassing Testing
- **Cost Drivers:**
  - Cost savings due to the potential reduction of 8 WYE and available for new work for 2.5 FTE
  - Transition costs are minimal (WSTF stated that no equipment transfer necessary)
  - No additional personnel needed at WSTF
- **Notes:**
  - Transportation costs captured by HQ Logistics Office
  - The Building will continue to be utilized for the following reasons
    - Contains MSFC's Environmental Gas Lab (EGL) -- required to sample and test centerwide propellants and pressurants distribution systems, clean rooms, and flow benches
    - Due to the fixed-price nature of MSFC's facilities base operations contract, closing this building would not save any of the Facilities O&M costs because the size of the building is significantly less than the size threshold required for a contract cost adjustment
    - Since the Utility costs are generally low (about $50K/year), it is more cost effective for MSFC to maintain the EGL at this location rather than incur the high cost and disruptions associated with relocating the EGL.

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Stennis Space Center (SSC)

Center Contact: Kern Witcher

- **Niche Work & Overflow Requirements**
  - Hypergolic Fluids handling/processing
- **Duplicated Capabilities**
  - Small Scale Ambient and Propulsion System Testing (E2)
  - Small Scale Ambient and Altitude Propulsion Systems Testing (E3)

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SSC: Hypergolic Fluids handling/processing

Office of Program Analysis and Evaluation

- **Description**:
  - Chemical analysis of air, water, soils, etc.
  - Hazardous and industrial waste characterization
  - Preparation and implementation of sampling plans

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Hypergolic Fluids handling/processing	$ -	$ (1)	$ (2)	$ (3)	$ (4)	$ (5)	$ (14)

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - No facility O&M savings as facility is currently mothballed
  - Minimal savings due to FTE attrition
  - May require TEA TEB training for WSTF personnel (TBD)
- Notes:
  - No customer currently identified
  - Not recommended for consolidation

Office of Program Analysis and Evaluation

SSC: Small Scale Ambient and Propulsion System Testing (E2)

- **Description**: The E-2 Test Facility was constructed to support materials development for the National Aerospace Plane (NASP) by subjecting special test articles to extreme temperature conditions. It is available for developmental testing projects involving hot gas, cryogenic fluids, gas impingement, inert gases, industrial gases, specialized gases, hydraulics, deionized and potable water. The E-2 is a highly flexible system that can be easily adapted to alternate open-loop control scenarios and closed-loop schemes with minimal hardware changes.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Small Scale Ambient and Propulsion System Testing (E2)	$ -	$ -	$ 1,300	$ (1,632)	$ (2,197)	$ (2,315)	$ (4,844)

If Mothballed

- Type: Duplicated Capabilities
- Cost Drivers:
  - Investment in run tanks for non-hypergol propellants
  - Facility build-up to reconfigure CSG systems to A3 skid designs
  - Transferring 16 vessels to WSTF
  - Significant savings due to reduced workforce
  - Does not include all transportation costs
- Notes:
  - This capability is currently under review by RPT and will be addressed in the PPBE activities
  - RPT will manage test assignments for performance at WSTF if facilities are capable of performing tests
  - NOT INCLUDED IN SUMMARY OF PHASE II CANDIDATES

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Office of Program Analysis and Evaluation

SSC: Small Scale Ambient and Altitude Propulsion Systems Testing (E3)

- **Description**: The E-3 Test Stand is a versatile test complex that is available for component development testing of combustion devices, rocket engine components and small/subscale component engines and boosters. Multi-cell (2) test facility with vertical and horizontal testing capabilities.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Small Scale Ambient and Altitude Propulsion Systems Testing (E3)	$ -	$ -	$ 700	$ 399	$ (210)	$ (219)	$ 670

- Type: Duplicated Capabilities

If Mothballed

- Cost Drivers:
  - Investment for RP or high pressure H2 upgrades (if required)
  - Transferring 18 vessels to WSTF
  - E3 facility to most likely be mothballed
  - Some savings due to reduced workforce
  - Does not include all transportation costs

- Notes:
  - This capability is currently under review by RPT and addressed in the PPBE activities
  - RPT will manage test assignments for performance at WSTF if facilities are capable of performing tests
  - NOT INCLUDED IN SUMMARY OF PHASE II CANDIDATES

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Office of Program Analysis and Evaluation

Kennedy Space Center (KSC)

Center Contact: Brian Nufer

- **Niche Work & Overflow Requirements**
  - Qualification/certification of Ares 1 hypergol flow meters
  - Perform validation and verification of GSE that supports Ares 1 and Orion
  - Fabrication of hypergol and high pressure gas servicing GSE
  - Pressure vessel certification assistance
  - Review Altair and Ares V GSE designs

Capability	FY2010	FY2011	FY2012		FY2014	FY2015	Total
Summary of KSC Niche Work & Overflow Capacity	$ (1,573)	$ (800)	$ (896)	$ (476)	$ (18)	$ (19)	$ (3,782)

- **Test Assignments & Shuttle Transition and Retirement**
  - The cold GHe HEX performance test for fall of 2010
  - High flow testing of cold GHe servicing
  - COPV testing
    - Not costed due to lack of future content identification
  - Orion CM post-flight processing
  - Shuttle retirement activities: OMS-RCS Decontamination, APU, Fuel Cell, …
    - Currently under review – see detailed sheet

Capability	FY2010	FY2011	FY2012		FY2014	FY2015	Total
Summary of KSC Testing & Shuttle Transition and Retirement	$ -	$ (2,872)	$ (1,929)	$ -	$ -	$ (166)	$ (4,967)

- **Duplicated Capabilities**
  - Hypergol material compatibility testing
    - See detailed sheet

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KSC: Shuttle Retirement Activities

Office of Program Analysis and Evaluation

- **Description**: Deservicing and decontamination of the shuttle orbiter aft propulsion system and forward reaction control system hypergols, APU's, Fuel Cell

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Equipment Relocation Shuttle OMS-RCS	$ -	$ (2,872)	$ (1,929)	$ -	$ -	$ -	$ (4,801)

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - ROM estimate is for OMS / RCS deservicing and decontamination only and is based on WSTF proposal to Shuttle Transition and Retirement
    - Estimate does not consider Pods/modules must remain certified for flight upon shipment from WSTF back to KSC (for ferry flight to museum)
    - Estimate does not include cost of designing and fabricating new handling fixtures as the current fixtures cannot exceed 5 mph
  - Does not include KSC costs to prepare equipment for transport to WSTF
- Notes:
  - **This capability is currently under review**
  - Option to relocate WSTF personnel to KSC to perform this work has been removed from the trade options
  - KSC has offered two options for consideration, slides included in the back-ups
  - This is a multi-step process involving operations at both Centers

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KSC: Hypergol material compatibility testing

Office of Program Analysis and Evaluation

- **Description**: Current capability of KSC (Wiltech and O&C), CCAFS (Hangar S), and WSTF.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Hypergol material compatibility testing	$ -	$ (352)	$ (363)	$ (374)	$ (385)	$ (396)	$ (1,870)

- Type: Duplicated Capabilities
- Cost Drivers:
  - No facility O&M savings as facilities will continue to be used for other activities
  - Reduction in KSC workforce to perform activities at WSTF
- Notes:
  - Evaluation of hardware and capabilities would need to be performed to determine what equipment can be used as spares and/or back up.
  - WSTF has most extensive capabilities for compatibility testing
  - Tests at KSC are funded by KSC projects (SSP, ISS, CxP, etc.)

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Office of Program Analysis and Evaluation

Johnson Space Center (JSC)

Center Contact: Mark Ferring

- **Test Assignments & Shuttle Transition and Retirement**
  - Orion Thruster Testing
  - Planetary Analog Field Test Site
  - Nitrogen Oxygen Recharge System
- **Duplicated Capabilities**
  - Offgassing of the Flight Hardware

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Office of Program Analysis and Evaluation

JSC: Orion Thruster Testing

- **Description**: Orion thruster testing

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Orion Thruster Testing	$ (413)	$ (982)	$ -	$ -	$ -	$ -	$ (1,394)

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - Reduction in JSC contractor workforce to perform activities at WSTF
  - Does not include contract termination or transportation costs
- Notes:
  - Estimates are from original discussions coordinated with the RPT Program Office
  - WSTF estimated costs to perform tests:
    - Command Module Estimate for TS 302: $1,339.92 ($K)
    - Service Module Estimate for TS 301: $2416.46 ($K)
  - Orion thruster testing that is planned to be performed at a contractor facility but could be done at WSTF
  - Study team presented this recommendation to the Technical Capabilities Working Group in June 2008 with a fully vetted study and business case analysis
  - In response to PDM 10 OCE 2, ESMD concurred that and additional CM/SM testing would be accomplished at WSTF and that testing being performed at Aerojet would be reavaluated if Orion contract modifications are made
  - **NOT INCLUDED IN SUMMARY OF PHASE II CANDIDATES**

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JSC: Planetary Analog Field Test Site

Office of Program Analysis and Evaluation

- **Description**: Provides realistic lunar surface analog to evaluate major systems through integrated systems testing in the field. Involves cargo and human lunar landers, lunar habitats, unpressurized rovers, pressurized rovers, other robotic systems, EVA test subjects, IVA and EVA tools and repair equipment, and scientific sample collection equipment in an environment with simulated lunar regolith.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Planetary Analog Field Test Site	$ (9)	$ (9)	$ (9)	$ (9)	$ (10)	$ (10)	$ (56)

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - Average O&M costs for facility
- Notes:
  - This testing has been performed in Arizona, and other remote locations in the past.
  - Storage of equipment would be maintained in the south high bay at WSTF.
  - Estimates include storage of equipment only, additional discussions are on-going to identify requirements to perform actual tests at WSTF.

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JSC: Nitrogen Oxygen Recharge System

Office of Program Analysis and Evaluation

- **Description**: Utilized on International Space Center post-Shuttle Program (unable to use ORCA)

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
NORS	$ (140)	$ (350)	$ (700)	$ (900)	$ (900)	$ (900)	$ (3,890)

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - ROM estimate provided by WSTF
- Notes:
  - **Under review with the ISS Program**

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JSC: Offgassing of the Flight Hardware

Office of Program Analysis and Evaluation

- **Description**: Toxicology lab analyzes samples from Shuttle and ISS and also performs offgassing of flight hardware. Preparation of standard samples and Volatile compound analyzer development.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Offgasing of the Flight Hardware	$ (70)	$ (73)	$ (75)	$ (78)	$ (81)	$ (84)	$ (461)

- Type: Duplicated Capabilities
- Cost Drivers:
  – Offgassing contractor support function transferred to WSTF
  – Transportation of hardware for analysis was not costed but expected to be minimal
- Notes:
  – Offgassing capability is a part of the toxicology lab (20% of work load) located in Bldg 37 at JSC
  – Offgassing facility processes about 20 items per year; mostly medical hardware

Glenn Research Center (GRC)

Center Contact: Rickey Shyne

Office of Program Analysis and Evaluation

- **Duplicated Capabilities**
  - Thermal Vac Propulsion Testing
  - Propulsion Testing

GRC: Thermal Vac Propulsion Testing

Office of Program Analysis and Evaluation

- **Description**: Chemical Rocket Engine Testing to Simulated Altitude of 120,000 ft. Up to 2000 pounds thrust

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Thermal Vac Propulsion Testing	$ -	$ -	$ 305	$ (449)	$ (483)	$ (517)	$ (1,144)

- **Type: Duplicated Capabilities**
- **Cost Drivers:**
  - No facility O&M savings as facility will continue to be utilized
  - Significant savings due to reduced workforce
  - Investment in propellant run tank upgrades for non-hypergolic propellants at TS403 and 405 would be required.
  - Storage of existing equipment at GRC not costed
- **Notes:**
  - **This capability is currently under review**
    - Estimated impact to WSTF needs to be evaluated to quantify schedule and cost impacts
  - GRC Notes: ETDP PCAD task agreements contain test commitments through FY2011. To move the current PCAD tests to WSTF would add a least an additional $4M cost and 2 year delay to GRC PCAD project.
  - Propellant skids from GRC could be transferred to WSTF instead of procuring new systems

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Office of Program Analysis and Evaluation

GRC: Propulsion Testing

- **Description**: Chemical Rocket Engine Testing. Up to 2000 pounds thrust

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Propulsion Testing	$ (179)	$ (313)	$ (342)	$ (371)	$ (400)	$ (430)	$ (2,034)

- **Type: Duplicated Capabilities**
- **Cost Drivers:**
  - No facility O&M savings as facility will continue to be reutilized
  - RCL Test 32 inactive to mothball costs estimated at $150K + $50K/year
  - Significant savings due to reduced workforce
- **Notes**:
  - WSTF note: no transfer of equipment
  - Mothball costs provided by GRC per 2008 RPTMB 5 year planning effort.

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Phase II Summary & Recommendations

Type	All values in real year 1000's dollars	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
	GRC	$ (179)	$ (313)	$ (37)	$ (820)	$ (882)	$ (946)	$ (3,178)
D	Propulsion Testing	$ (179)	$ (313)	$ (342)	$ (371)	$ (400)	$ (430)	$ (2,034)
D	Thermal Vac Propulsion Testing	$ -	$ -	$ 305	$ (449)	$ (483)	$ (517)	$ (1,144)
	JSC	$ (210)	$ (423)	$ (775)	$ (978)	$ (981)	$ (984)	$ (4,351)
T	Nitrogen Oxygen Recharge System	$ (140)	$ (350)	$ (700)	$ (900)	$ (900)	$ (900)	$ (3,890)
D	Offgasing of the Flight Hardware is the only element under consideration	$ (70)	$ (73)	$ (75)	$ (78)	$ (81)	$ (84)	$ (461)
	KSC	$ (1,573)	$ (4,023)	$ (3,187)	$ (849)	$ (403)	$ (581)	$ (10,617)
T	Equipment Relocation Shuttle OMS-RCS	$ -	$ (2,872)	$ (1,929)	$ -	$ -	$ -	$ (4,801)
D	Hypergol Material Compatibility Testing	$ -	$ (352)	$ (363)	$ (374)	$ (385)	$ (396)	$ (1,870)
N	Fabrication of hypergol and high pressure gas servicing GSE (Orion and Ares 1)	$ (1,071)	$ (333)	$ -	$ -	$ -	$ -	$ (1,404)
N	Pressure vessel certification assistance	$ (453)	$ (467)	$ (481)	$ -	$ -	$ -	$ (1,400)
N	Perform validation and verification of GSE that supports Ares 1 and Orion at WSTF	$ -	$ -	$ (415)	$ (476)	$ -	$ -	$ (890)
T	Orion CM post-flight processing	$ -	$ -	$ -	$ -	$ -	$ (166)	$ (166)
N	Qualification/certification of Ares 1 hypergol flow meters	$ (49)	$ -	$ -	$ -	$ -	$ -	$ (49)
N	Review Altair and Ares V GSE designs	$ -	$ -	$ -	$ -	$ (18)	$ (19)	$ (37)
	MSFC	$ (640)	$ (683)	$ (721)	$ (760)	$ (800)	$ (842)	$ (4,446)
D	MCRF Total	$ (640)	$ (683)	$ (721)	$ (760)	$ (800)	$ (842)	$ (4,446)
	SSC	$ -	$ (1)	$ (2)	$ (3)	$ (4)	$ (5)	$ (14)
N	Hypergolic Fluids handling/processing	$ -	$ (1)	$ (2)	$ (3)	$ (4)	$ (5)	$ (14)
	Grand Total	$ (2,602)	$ (5,443)	$ (4,723)	$ (3,410)	$ (3,070)	$ (3,358)	$ (22,606)

TYPES: T- Test Assignments and Shuttle Transition & Retirement | N- Niche Work and Overflow Requirements | D - Duplicated Capabilities

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Recommendations

- Implement changes to effectively execute the transfer of functions described on the previous page to WSTF – functions, testing, and associated funding
- For 2011 budget guidance
  - MSFC MCRF functions, testing, and funding
  - KSC Hpyergol Materials Compatibility Testing
  - GRC Thermal Vac and Propulsion testing capabilities
  - Perform all niche / overflow manufacturing, cleaning, calibration at WSTF
- Remove assessments on NASA Programs and Projects beginning in FY2011
- Fully fund remaining WSTF Gap to allow reduction of assessment on external customers (currently > 60%)
  - Assessment needs to be reasonable and fair for services provided
- WSTF establish relationships with each Center to facilitate execution of niche / overflow work and track identified items
- Further evaluate Agency's small propulsion test stand utilization through RPT for closures / consolidations: MSFC 115 / 116, SSC E2 / E3
- Work with JPL to identify candidates for consideration

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Phase I and Phase II Budget Summary

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

$M	FY09	FY10	FY11	FY12	FY13	FY14	FY15	10-15 Total
March 2008 HSCF II Gap	$10,700.0	$0.0	$24,200.0	$29,700.0	$29,700.0	$33,000.0		$116,600.0
April 2009 HSCF III Gap	$0.0	$2,600.0	$14,900.0	$23,200.0	$27,600.0	$31,200.0	$32,300.0	$131,800.0
Sept 2009 Right Size Gap		$4,813.0	$13,068.0	$17,152.0	$20,016.0	$21,768.0	$22,887.0	$99,704.0
Right Size Totals		$66,040	$53,297	$50,191	$49,982	$49,496	$50,743	$318,118
Total Available Funding		$53,828	$42,435	$36,710	$34,731	$31,744	$31,925	$231,373
Right Size Gap without assessments		$12,212	$10,862	$13,481	$15,251	$17,752	$18,818	$88,376
Program Assessments		$10,700	$2,400	$2,400	$2,400	$2,400	$2,400	$22,700
Right Size Gap with assessments		$1,512	$8,462	$11,081	$12,851	$15,352	$16,418	$65,676
Available For New Work (AFNW)		$0.0	$1,459.0	$2,077.0	$3,068.0	$3,434.0	$3,550.0	$13,588.0
Total Gap (December 2009)		**$1,512**	**$9,921**	**$13,158**	**$15,919**	**$18,786**	**$19,968**	**$79,264**
Potential Phase II Funding		$2,810	$5,879	$5,647	$3,684	$3,317	$3,628	$24,964
Gap with potential Phase II Funding		$1,298	$4,042	$7,511	$12,235	$15,469	$16,340	$54,300
Gap w/Phase II and Excluding AFNW		$1,298	$2,583	$5,434	$9,167	$12,035	$12,790	$40,711

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WSTF Core Capabilities – Budget Summary

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

Black (positive) gaps are assumed to reduce the overall WSTF gap

CMO costs in FY12-15 are still under evaluation and are expected to decrease, affecting gap values

FY	Propulsion			Laboratories			Hardware Processing			CMO		Total		
	Total Cost	Gap	Gap Phase II	Total Cost	Gap	Gap Phase II	Total Cost	Gap	Gap Phase II	Total Cost	Gap	Total Cost	Gap*	Gap Phase II*
FY10	$17,453	$0	$228	$11,747	($1,022)	($172)	$8,640	$10	$1,742	$28,200	($500)	$66,040	($1,512)	$1298
FY11	$13,840	$1,344	$2,378	$7,932	($1,289)	$169	$4,396	($1,057)	$2,330	$27,129	($7,460)	$53,297	($8,462)	($2,583)
FY12	$10,274	$750	$1,454	$7,934	($2,370)	($311)	$4,499	($1,708)	$1,176	$27,484	($7,753)	$50,191	($11,081)	($5, 434)
FY13	$8,888	($120)	$703	$8,204	($2,547)	($435)	$4,582	($1,915)	($1,166)	$28,308	($8,269)	$49,982	($12,851)	($9,167)
FY14	$7,368	($1,600)	($713)	$8,304	($2,639)	($473)	$4,769	($2,365)	($2,101)	$29,055	($8,748)	$49,496	($15,352)	($12,035)
FY15	$7,568	($1,800)	($848)	$8,469	($2,787)	($565)	$4,860	($2,605)	($2,151)	$29,846	($9,226)	$50,743	($16,418)	($12,790)
6 Yr Total	$65,391	($1,426)	$3,202	$52,590	($12,654)	($1,787)	$31,746	($9,640)	($170)	$170,022	($41,956)	$319,749	($65,676)	($40,711)

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M - $4M per yr.

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Closed Session – Procurement Sensitive

BACK-UP

Propulsion Summary

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

Black (positive) gaps are assumed to reduce the overall WSTF gap

FY	Projected		Required		Phase II	
	Funding (K)	WYE	Cost (K) (Gap)	WYE	Projected Funding	Projected Gap
FY10	$17,453	95	$17,453 0	95	$228	$228
FY11	$15,184*	88	$13,840 $1,344	88	$1,033	$2,377
FY12	$11,024*	66	$10,274 $750	66	$702	$1,452
FY13	$8,768*	56	$8,888 ($120)	57	$820	$700
FY14	$5,768*	42	$7,368 ($1,600)	49	$883	($717)
FY15	$5,768 *	42	$7,568 ($1,800)	49	$947	($853)

* Projected Funding assumes that unconfirmed test programs materialize.

- Funding and Staffing levels include costs/personnel covered by test programs, maintenance funding and core capability requirements (RPT)
  - Previous presentations only included maintenance and core capability numbers
- 3% Inflation included starting FY11
- Assumes assessments on all projects in FY10 and only non-NASA programs in FY11 and beyond.

Propulsion reduction from 95 to 49 WYEs (48%) and to 3 of 9 test stands

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Laboratories Summary

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

Black (positive) gaps are assumed to reduce the overall WSTF gap

FY	Projected		Testing Requirements	RTP and CA Requirements	Total WYE Needed	Total Requirements	Phase II	
	Funding (K)	WYE	Cost (K)	Cost (K)	WYE	Cost (K) (Gap)	Projected Funding	Projected Gap
FY10	$10,725	63	$6,524	$5,223	73	$11,747 ($1,022)	$850	($172)
FY11	$6,643	38	$2,552	$5,380	67	$7,932 ($1,289)	$1,458	$169
FY12	$5,564	31	$2,393	$5,541	57	$7,934 ($2,370)	$2,059	($311)
FY13	$5,657	31	$2,496	$5,708	57	$8,204 ($2,547)	$2,112	($435)
FY14	$5,665	30	$2,425	$5,879	56	$8,304 ($2,639)	$2,166	($473)
FY15	$5,682	29	$2,414	$6,055	55	$8,469 ($2,787)	$2,222	($565)

Laboratories reduction from 89 to 55 WYEs 38%)

- Funding gaps are associated with lack of maintenance / RTP funding in FY11 and beyond
- 3% Inflation included starting in FY11
- Assumes assessments on all projects in FY10 and only non-NASA programs in FY11 and beyond.

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Hardware Processing

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

Black (positive) gaps are assumed to reduce the overall WSTF gap

FY	Depot Projected		Depot Required		Enabling Capabilities Projected		Enabling Capabilities Required		Phase II	
	Funding (K)	WYE	Cost (K) (gap)	WYE	Funding (K)	WYE	Cost (K) (gap)	WYE	Projected Funding*	Projected Gap *
FY10	$4,516	41	$4,516 0	41	$4,134	37	$4,124 $10	37	$1,732	$1,742
FY11	$210	2	$380 ($170)	4	$3,129	28	$4,016 ($887)	35	$3,387	$2,330
FY12	$75	1	$363 ($288)	3	$2,716	23	$4,136 ($1,420)	35	$2,884	$1,176
FY13	$25	0.25	$322 ($297)	3	$2,642	22	$4,260 ($1,618)	35	$749	($1,166)
FY14	$75	1	$381 ($306)	3	$2,329	19	$4,388 ($2,059)	35	$264	($2,101)
FY15	$25	0.25	$340 ($315)	3	$2,230	18	$4,520 ($2,290)	35	$454	($2,151)

* Phase II projected funding includes enabling capability work contributions from additional Phase II work in Labs and Propulsion. Phase II projected gap includes both Depot and Enabling Capabilities

- 3% Inflation included
- Assumes predicted work from Propulsion and Laboratories
- Enabling Capability minimum costs provide very basic capacity, additional capacity will be program/project responsibility
- FY09 ~ $4,420 and 40 WYE for Depot and $7,084 and 65 WYE for Enabling Capabilities

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CMO Summary

as of 12/04/2009

Note: Red numbers indicate negative (gap) values

FY	Anticipated		Requirements	
	Funding (K)	WYE	Cost (K) (gap)	WYE
FY10	$27,700*	201	$28,200 ($500)	205
FY11	$19,669**	143	$27,129 ($7,460)	181
FY12	$19,731**	143	$27,484 ($7,753)	171
FY13	$20,039**	146	$28,308 ($8,269)	171
FY14	$20,307**	148	$29,055 ($8,748)	171
FY15	$20,620**	150	$29,846 ($9,226)	171

- 3% Inflation included
- * Fy10 includes assessments on all projects
- **Fy11 and beyond includes assessment only on Non-NASA reimbursable projects.
- Expect reductions in requirements FY11 and beyond due to actions previously defined

New Protective Services contract will increase the CMO and overall costs by approximately $ 3M to $4M / yr.

TDRS ground station not included

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NASA Office of Program Analysis and Evaluation

Core Competencies at NASA Centers

Capabilities considered but not costed

All Centers/SSC: Gas and Materials Analysis

Office of Program Analysis and Evaluation

- **Description**:
  - Determination of contaminants / impurities
  - Assessing contamination from the transfer of propellants and gas system
  - Verify the cleanliness level (NVR and particulate analysis) of components /hardware
  - Identifies unknown mtl/cont, determines failure mode and root cause analysis on components and materials

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Gas and Materials Analysis	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Niche & Overflow Capacity
- Cost Drivers:
  - Not costed
- Notes:
  - Center core capability
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

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Office of Program Analysis and Evaluation

All Centers/SSC: Instrument Calibration

- **Description**: Existing large volume instrumentation calibration for all SSC test facilities and supporting test infrastructure (site High Pressure Gas Facility, High Pressure Industrial Water system, Cryogenic propellant supply dock. receiving and transport facility) regularly utilized supporting ongoing SSC test projects.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Instrument Calibration	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Excess Work Performed at WSTF
- Cost Drivers:
  - Not costed
  - Would require investments to accommodate UHP calibration
- Notes:
  - SSC core capability
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

All Centers/GSFC: Calibration Items

Office of Program Analysis and Evaluation

- **Description**: Calibration of items at GSFC

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Calibration	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Excess Work Performed at WSTF
- Cost Drivers:
  - Not costed
- Notes:
  - GSFC core capability
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

Office of Program Analysis and Evaluation

All Centers/JSC: Calibration of Test Equipment

- **Description**: Calibration services for electrical/electronic, physical/mechanical and dimensional instruments and tools used in flight, non-flight and ground support applications.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Calibration of Test Equipment	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Not costed
- Notes:
  - Center core capability
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

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Office of Program Analysis and Evaluation

All Centers/SSC: Fabrication

- **Description**:
  - Weld/Fabrication Shop provides gas welding or brazing and arc welding in accordance with ASME and American Welding Society (AWS) standards.
  - Welders are certified to weld a wide range of metals (carbon steel, aluminum, and stainless steel)
  - Employing Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW)

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Fabrication	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Excess Work Performed at WSTF
- Cost Drivers:
  - Not costed
- Notes:
  - SSC core capability
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

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All Centers/GSFC: Fabrication Items

Office of Program Analysis and Evaluation

- **Description**: Fabrication of items at GSFC

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Fabrication	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Excess Work Performed at WSTF
- Cost Drivers:
  - Not costed as data is unavailable at this time
- Notes:
  - $3-4M of fabrication work at GSFC is outsourced per year
  - GSFC is working with WSTF to determine what items can be outsourced
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

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Office of Program Analysis and Evaluation

All Centers/SSC: Machining

- **Description**: Operates lathes, milling machines, boring mills, shaers, drill presses,and grinders. The shop is also equipped with one Hurco, three-dimensional, computer controlled machine having a 52-inch capacity along the "x" axis, 30-inch capacity along the "y" axis, and 24-inch capacity along the "z" axis

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Machining	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  – Not costed
- Notes:
  – Center core capability
  – Not recommended for consolidation
  – Potential niche overflow work to WSTF

All Centers/SSC: Component Processing

Office of Program Analysis and Evaluation

- **Description**: unique, large and high pressure component processing (assembly, modification and/or repair) capability and expertise, is regularly utilized supporting ongoing SSC test projects.
  - Hydrostatic testing can be performed up to 30,000 psi
  - Pneumatic testing up to 15,000 psi
  - Cryogenic testing of components, up to 30"
  - Level 10K clean room.
  - Hypergolic GSE components cleaning and/or calibration: Funded by KSC projects (SSP, ISS, CxP, etc.). It is not too practical to ship contaminated parts across the U.S. for this. Wiltech cleans and decontaminates about 1600 hypergol components annually. The calibration lab calibrates TBD hypergol components annually.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Component Processing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Not costed
- Notes:
  - Center core capability
  - Not recommended for consolidation
  - Potential niche overflow work to WSTF

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All Centers/SSC: Environmental Monitoring

Office of Program Analysis and Evaluation

- **Description**:
  - Chemical analysis of air, water, soils, etc.
  - Hazardous and industrial waste characterization
  - Preparation and implementation of sampling plans

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Environmental Monitoring	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Not costed
- Notes:
  - Center core capability
  - Not recommended for consolidation
  - Requirement for independent review of environmental conditions may be a potential niche for WSTF

MSFC: Hypervelocity Impact Testing

Office of Program Analysis and Evaluation

- **Description**:
  - Exploding Wire Gun
  - Low to very high hypervelocity; capability relocated to NASA from Army in 2005.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Hypervelocity Impact Testing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- **Type: Test Assignments & Shuttle Transition and Retirement**

- **Cost Drivers:**
  - No costs in study timeframe

- **Notes:**
  - Future capability that MSFC wants to do the development but do the testing at WSTF
  - Impact would require an additional section on building 272 for WSTF
  - Currently MSFC is planning to have 30K for one year demo; future plans are dependent on demo.
  - Facility does not exist at WSTF; 4-5 yr timeline

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Office of Program Analysis and Evaluation

MSFC: Ares V Development

- **Description**:
  - Propulsion Testing
  - Hyper Materials and Component Testing

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Ares V Development	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- **Type: Test Assignments & Shuttle Transition and Retirement**

- **Cost Drivers:**
  - No costs in study timeframe

- **Notes:**
  - Comparable hydrazine systems will exist on the Ares V vehicle, resulting in similar opportunities for WSTF
  - Supported by previous studies:
    - **IAS-** I&A Study (2007)
    - **OCE-** Office of Chief Engineer (NASA) 2008
  - Ares I and Ares V work is highly dependent on direction the Agency takes as a follow-up to the U.S. Human Space Flight Plans Committee report

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Office of Program Analysis and Evaluation

MSFC: Ares I Upper Stage Composite Overwrap tank testing

- **Description**:
  - Overwrap tank testing

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Ares I Upper Stage Composite Overwrap tank testing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- **Type: Test Assignments & Shuttle Transition and Retirement**
- **Cost Drivers:**
  - Not costed
- **Notes:**
  - **Currently under review**
  - Boeing under contract to Upper Stage to provide COPV tanks
  - Supplier not yet selected
  - Extent of dev/qual testing not yet finalized
  - Test site subject to negotiations with supplier
  - WSTF would be well suited for testing
  - Supported by previous studies:
    - **KR**- **K**line **R**eport on Hypervelocity Testing (1995)
    - **TCB**- **T**ransition **C**ontrol **B**oard action 07-03072007 (Aug 2008), Third party assessment of WSTF capabilities

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MSFC: Ares I US RoCS & ReCS hydrazine component compatibility qual testing

Office of Program Analysis and Evaluation

- **Description**:
  - Hydrazine component compatibility qual testing
  - Hyper Materials and Component Testing

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Ares I US RoCS & ReCS hydrazine component compatibility qual testing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- **Type: Test Assignments & Shuttle Transition and Retirement**

- **Cost Drivers:**
  - Not costed

- **Notes:**
  - Desired task; will be done at WSTF but currently not funded in Cx PPBE

MSFC: Ares I US material hydrazine compatibility & adiabatic compression detonation testing

Office of Program Analysis and Evaluation

- **Description**:
  - US material hydrazine compatibility & adiabatic compression detonation testing
  - Hyper Materials and Component Testing

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Ares I US material hydrazine compatibility & adiabatic compression detonation testing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- **Type: Test Assignments & Shuttle Transition and Retirement**

- **Cost Drivers:**
  - Not costed

- **Notes:**
  - Desired task; will be done at WSTF but currently not funded in Cx PPBE
  - Current plan is analysis and some testing on HFTA

MSFC: Ares I Upper Stage RoCS & ReCS Subsystem Qual Hot Fire Testing (HFTA)

Office of Program Analysis and Evaluation

- **Description**:
  - Ares I Upper Stage RoCS & ReCs
  - Subsystem Qualification Hot Fire testing (HFTA)

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Ares I Upper Stage RoCS & ReCS Subsystem Qual Hot Fire Testing (HFTA)	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Test Assignments & Shuttle Transition and Retirement

- Cost Drivers:
  - Not costed: already in baseline

- Notes:
  - Baselined to be conducted at WSTF
  - WSTF has identified need to shift funding from FY13 to FY12; in work
  - Additional plus-up likely required; not yet quantified

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Office of Program Analysis and Evaluation

KSC: Qualification/certification of Ares 1 hypergol flow meters

- **Description**: Used during Ares 1 RoCS/ReCS N2H4 servicing. Funded by KSC (LX).

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Qualification/certification of Ares 1 hypergol flow meters at WSTF	$ (49)	$ -	$ -	$ -	$ -	$ -	$ (49)

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Reflects amount of work scoped for effort to be directed to WSTF
  - No facility O&M or workforce savings as work is currently not performed at KSC
- Notes:
  - Original intent of KSC was to complete this task at an external vendor

Office of Program Analysis and Evaluation

KSC: Perform validation and verification of GSE that supports Ares 1 and Orion

- **Description**: Hypergol and other subsystem servicing GSE will need to pass verification and validation prior to first use on the flight vehicle.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Perform validation and verification of GSE that supports Ares 1 and Orion	$ -	$ -	$ (415)	$ (476)	$ -	$ -	$ (890)

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - No facility O&M savings as facilities will continue to be utilized
  - Reduction in KSC workforce to perform activities at WSTF
- Notes:
  - Work is planned at KSC; prefer to perform V&V at WSTF
  - Most of this GSE is made to be portable so it may be possible to transport it to WSTF for verification and validation

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Office of Program Analysis and Evaluation

KSC: Fabrication of hypergol and high pressure gas servicing GSE

- **Description**: Hypergol and high pressure gas servicing GSE fabrication

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Fabrication of hypergol and high pressure gas servicing GSE	$ (1,071)	$ (333)	$ -	$ -	$ -	$ -	$ (1,404)

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Reduction in KSC workforce to perform activities at WSTF
- Notes:
  - Currently planned to utilize KSC GSE IDIQ contract. The only contractual guarantee is that the contractors that have been awarded an IDIQ contract receive a minimum order (in this case the actual profit on the minimum order).
  - Most of GSE is made to be portable so it may be possible to transport it from WSTF if it were fabricated there.

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KSC: Pressure vessel certification assistance

Office of Program Analysis and Evaluation

- **Description**: Plan includes testing, NDE, and analysis. Change in KNPR 8715.3 (Old - appendix E section 16.0; New - section 13.14.4) requirements for recertification from older methods to risk based analysis.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Pressure vessel certification assistance	$ (453)	$ (467)	$ (481)	$ -	$ -	$ -	$ (1,400)

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Personnel to perform functions at WSTF as determined by KSC
  - TDY costs for WSTF to support KSC onsite
- Notes:
  - ISS & Spacecraft Processing has a total of 182 pressure vessels that will need to go through this certification.
    - Other organizations at KSC also require certification; effort TBD.
  - WSTF would support remotely but travel to KSC for onsite testing and meetings

KSC: Review Altair and Ares V GSE designs

Office of Program Analysis and Evaluation

- **Description**: Independent review of GSE designs that will support Ares V and Altair.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Review Altair and Ares V GSE designs	$ -	$ -	$ -	$ -	$ (18)	$ (19)	$ (37)

- Type: Niche Work & Overflow Capacity
- Cost Drivers:
  - Personnel to perform functions at WSTF as determined by KSC
- Notes:
  - Assumed that KSC Orion and Ares 1 GSE designs will be mature by FY2011 but review will be done in FY14-15 time frame.
  - Additional money from KSC to support this rather than transferred money.

Office of Program Analysis and Evaluation

KSC: The cold GHe HEX performance test for fall of 2010

- **Description**: H/W will be installed on the CLV ML. LH2 flowrates & quantity higher than possible at KSC (except pads). Test requirements document and test matrix are currently in work by KSC engineering.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Cold GHe HEX performance test	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - Costs not provided due to contract sensitivity (provided by KSC to HQ PA&E)
- Notes:
  - KSC future work to be presented to management and advertised to WSTF, MSFC, SSC, GRC/PBS, GRC, and KSC for the testing phase.
  - The schedule for the CGHe HEX is very aggressive. The test facility must have the hydrogen infrastructure (flare stack, haz gas, etc) or hydrogen experience already available. Any delay could severely impact the ready to support date for the ML.

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KSC: High flow testing of cold GHe servicing

Office of Program Analysis and Evaluation

- **Description**: Next generation prototype testing of cold GHe systems for CaLV ML. This is a follow-on to cold GHe HEX above. Heavy LH2 bath heat exchanger needed. New expanded foam heat exchanger development work being funded by ETDP/CFM for CxP/GO and by RPTMB. Lab scale prototype exists at KSC in cryo lab.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
High flow testing of cold GHe servicing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - Not costed as data was not available due to contractual restrictions
- Notes:
  - KSC have no budgeted funds at this time specifically set aside for CaLV cold GHe HEX testing
  - Future work to be advertised to other Centers

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Office of Program Analysis and Evaluation

KSC: COPV testing

- **Description**: Composite Overwrap Pressure Vessel (COPV) stress rupture (failure detection), lifetime, NDE, and compatibility testing.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
COPV testing	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Test Assignments & Shuttle Transition and Retirement
- Cost Drivers:
  - Not costed due to lack of future content identification
- Notes:
  - Lacks funding at KSC and KSC does not have the capability to do this sort of testing
  - KSC needs this data to help determine the processing safety requirements for servicing and use of COPVs.

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KSC: Equipment Relocation Shuttle OMS-RCS (WSTF Option)

Office of Program Analysis and Evaluation

- **Description**: Deservicing and decontamination of the shuttle orbiter aft propulsion system and forward reaction control system hypergols.

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Equipment Relocation Shuttle OMS-RCS	$ -	$ (2,872)	$ (1,929)	$ -	$ -	$ -	$ (4,801)

- Type: Test Assignments & Shuttle Transition and Retirement (STAR)
- Cost Drivers:
  - ROM Estimate based on WSTF proposal to Shuttle Transition and Retirement (STAR)
    - Estimate does not consider Pods/modules must remain certified for flight upon shipment from WSTF back to KSC (for ferry flight to museum)
    - Estimate does not include cost of designing and fabricating new handling fixtures as the current fixtures cannot exceed 5 mph
- Notes:
  - **This capability is currently under review**
  - Option to relocate WSTF personnel to KSC to perform this work has been removed from the trade options

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KSC: Equipment Relocation Shuttle OMS-RCS (KSC Option #1)

Office of Program Analysis and Evaluation

- **Description**: **Option #1: Transport Pods/Modules to WSTF After Deserviced & Safed**

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Transport Pods/Modules to WSTF After Deserviced & Safed	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Test Assignments & Shuttle Transition and Retirement (STAR)
- Cost Drivers:
  - No costs were provided by KSC
  - 40% of the work content for configuring a pod/module for display is the deservicing & purging of the modules
    - Pods /modules have to go to the HMF for horizontal and vertical drain operations and prep for shipment
  - **30% is hardware removal per the End State Subsystem Requirements Document (ESSRD)**
    - **This is the only portion of the pod/module T&R that would be available for WSTF to perform**
  - The final 30% is configuring the pods/modules for ferry flight and display
- Notes:
  - KSC's Need Date for Pods/Module Installation for Ferry Flight:
    - 1st Ship Set Aug. 2011
    - 2nd Ship Set Nov. 2011
    - 3rd Set may be required for OV-101 processing but is currently TBD

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Office of Program Analysis and Evaluation

KSC: Equipment Relocation Shuttle OMS-RCS (KSC Option #2)

- **Description** : **Option #2: Shipping of Removed Hardware to WSTF for Final Disposition**

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Transport Pods/Modules to WSTF After Deserviced & Safed	$ -	$ -	$ -	$ -	$ -	$ -	$ -

- Type: Test Assignments & Shuttle Transition and Retirement (STAR)
- Cost Drivers:
  - No costs were provided by KSC
- Notes:
  - KSC has no issues with option 2, excluding the thrusters and the OMS engines
  - KSC's plan is to decontaminate the hardware in place and only remove the valves that contained soft goods
    - It is not planned to remove thrusters or OMS engines, only the portions of these components that contained soft goods
    - This eliminates the need for thruster and OMS engine simulators for the ferry flight and their corresponding development/fabrication costs

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KSC: Orion CM post-flight processing

Office of Program Analysis and Evaluation

- **Description**: Baselined to occur in MPPF east footprint and then move to O&C at KSC. Activities may include N2H4 deservicing, decontamination, and disassembly of subsystems (and component refurbishment).

Capability	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total
Orion CM post-flight processing at WSTF	$ -	$ -	$ -	$ -	$ -	$ (166)	$ (166)

- **Type: Test Assignments & Shuttle Transition and Retirement**
- **Cost Drivers:**
  - Reduction in KSC workforce to perform activities at WSTF
  - No facility O&M savings as facility will continue to be used at KSC
  - Additional WSTF costs associated with specific fixturing for test specific hardware not included
- **Notes:**
  - Minimal impact; potential work to be performed
  - Utilized 11/4/09 Cx Manifest for Orion I; wouldn't be processed at WSTF until FY15
  - No direct transportation costs associated with processing Orion CM assumed as WSTF to be en route to KSC
  - Could eliminate the need for shipment of CM assembly to KSC O&C for DD1149, would only ship reusable LRUs. (WSTF TS328)
  - Some of these activities are currently planned for the O&C and could require LM personnel to complete the work (contract modification)
  - Trade space still includes deservicing at the port (San Diego)
    - Could still disassemble CM at WSTF with this option
  - KSC would still be involved with deservicing/decon GSE design
    - Designs are already underway and at a 60% level

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Appendix D. White Sands Test Facility "Right Size" - WSTF PRG Guidance and Center Director Feedback, dated January 29, 2010

Topics

- Overview of PRG Guidance
- Site Specific Guidance
- OMS / RCS Decon Update
- Center Director Response – provided by centers
- Summary / Direction – discussion

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Overview of PRG Guidance

- 6 items taken into consideration for inclusion in 2012 PRG
  - 1 item each from MSFC, KSC, and JSC; 2 items from GRC; 1 general item for all Centers
- Most significant impact is not from the transfer of the O&M of the facilities but from the consolidation of testing and activities to be performed in the facilities
  - Most of the facilities cross-utilize personnel from multiple test facilities to perform maintenance to minimize overall costs
- In nearly all cases, WSTF has the ability to perform the identified functions without the transfer of equipment
  - Transfer of the propellant conditioning skids from GRC may be required to provide same test capability
    - WSTF has a propellant conditioning capability designed to meet same conditions but capability has not been demonstrated

2012 PRG Guidance for MSFC

- Close the MSFC Materials Combustion Research Facility (Building 4623) and transfer all functions, testing, and related funding to WSTF
  - Equipment and test hardware will be evaluated for utilization as spares and relocated under separate action – both to WSTF and for other MSFC lab functions
    - SOMD / ESMD provide $300k for dismantle and shipping of spares to WSTF
    - Once all spares have been identified for use by WSTF and MSFC remaining will be identified as excess government equipment
  - MSFC maintain Environmental Gas Lab (EGL) for sampling and testing center-wide propellant and pressurant distribution systems, cleanrooms, and flow benches
    - MSFC to evaluate transferring EGL to a different location on site with the goal to close and demolish Building 4623
      - MSFC to report to Transition Control Board within 6 months on the ability to close and demolish Building 4623

Materials Combustion Research Facility (MCRF)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
MSFC MCRF Capability O&M	$ 155	$ 160	$ 166	$ 173	$ 179	$ 186	$1,019	*Utilized MSFC estimates and inflationary assumptions*
WSTF Right-Size O&M Estimate	$ 500	$ 515	$ 530	$ 546	$ 563	$ 580	$3,234	*To maintain MCRF capabilities at WSTF facilities*
MSFC Projected Testing	$1,411	$1,455	$1,502	$1,550	$1,599	$1,650	$9,166	*Utilized MSFC estimates and inflationary assumptions*

Recommended Transfer

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2012 PRG Guidance for KSC

- Close the KSC Hypergol material Compatibility Testing lab and transfer all functions, testing, and related funding to WSTF
  - Equipment and test hardware will be evaluated for utilization as spares and relocated under separate action – both to WSTF and for other KSC lab functions
    - SOMD / ESMD provide $300k for dismantle and shipping of spares to WSTF
    - Once all spares have been identified for use by WSTF and KSC remaining will be identified as excess government equipment

Hypergol Material Compatibility Testing								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
KSC Capability O&M	$ -	$ -	$ -	$ -	$ -	$ -	$ -	*Minimal O&M captured during test ODC costs*
WSTF Right-Size O&M Estimate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	*Assumed to be minimal*
KSC Projected Testing	$ -	$ 372	$ 384	$ 395	$ 407	$ 419	$1,977	*Assumes test rate of ~275 items/yr. Doesn't include O&M*

Recommended Transfer

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2012 PRG Guidance for GRC

- Close the GRC RCL Test Stand 32, and close, upon completion of the current test cycle, the Altitude Combustion Stand (ACS) and transfer all functions, testing, and related funding for both facilities to WSTF
  - Equipment and test hardware will be evaluated for utilization as spares and relocated under separate action – both to WSTF and for other GRC lab functions
    - SOMD / ESMD provide $800k to dismantle and relocate ACS propellant conditioning skids to WSTF
    - Seek Agency Strategic Institutional Investment funds to demolish ACS
    - Seek Agency Strategic Institutional Investment funds to demolish RCL Test Stand 32

Thermal Vac Propulsion testing at Altitude Combustion Stand (ACS)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
GRC Capability O&M	$ -	$ -	$ 179	$ 184	$ 190	$ 195	$ 748	*1 FTE/yr (avg rate$123.5K) plus $45K CMO*
2009 RPT Strategic Assessment	$ -	$ -	$ 372	$ 384	$ 395	$ 407	$1,558	*2009 RPT Strategic Assessment ($351K/yr)*
GRC Projected Testing	$ -	$ -	$1,197	$1,232	$1,269	$1,307	$5,006	*FY2012 Operating Costs provided by GRC*
Propulsion Testing at RCL Test Stand 32 (ambient testing)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
GRC Capability O&M	$ -	$ -	$ 113	$ 117	$ 120	$ 124	$ 474	*0.5 FTE/yr (avg rate$123.5K) plus $45K CMO*
2009 RPT Strategic Assessment	$ -	$ -	$ 127	$ 131	$ 135	$ 139	$ 533	*2009 RPT Strategic Assessment ($120K/yr)*
GRC Projected Testing	$ 901	$ 928	$ 956	$ 984	$1,014	$1,044	$5,827	*FY2010 Operating Costs provided by GRC*

Recommended Transfer

Note 1: RPT has received a wide variety of estimates for per year costs to maintain the GRC facilities (2009 RPT Strategic Assessment for an inactive state was ~$470k for the two facilities, initial WSTF Right Size activity normalized estimate was ~$900k for both facilities, most recent estimate was ~$80k plus 1.5 fte for both facilities. RPT experience with similar sized and capable facilities is in the range of $300k for an ACS class facility ($600k for two facilities).

Note 2: In November 2006 the NASA Office of Inspector General, in Audit Report No. ML-07-001 on the construction of the ACS found "existing facilities could perform the rocket propulsion testing capability that the ACS would provide, making the requirement for the ACS facility questionable."

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2012 PRG Guidance for JSC

- Close the JSC Flight Hardware Offgassing Lab and transfer all functions, testing, and related funding to WSTF

Off gassing of Flight Hardware								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	Notes
JSC Capability O&M	$ -	$ -	$ -	$ -	$ -	$ -	$ -	*Minimal*
WSTF Right-Size O&M Estimate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	*Minimal*
JSC Projected Testing	$ 70	$ 73	$ 75	$ 78	$ 81	$ -	$ 378	*Assumes test rate of ~20 items/yr. Doesn't include O&M*

Recommended Transfer

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2012 PRG Guidance for all Centers

- Perform excess fabrication, testing, cleaning, machining, environmental, calibration, and component processing that falls within WSTF area of expertise at WSTF prior to outside vendors
  - WSTF report semi-annually to the Transition Control Board on extra work being transferred
  - Centers report yearly on transferred work and planned activities to be sent to WSTF

Update on OMS / RCS Decon

- At the Jan 20 TCB SSP reported that decon work could be performed at either WSTF or KSC
- Significant driver for determining location of activities was receipt of permits to transfer contaminated modules to WSTF
- Susan Kinney / OPII given action to work with SSP, WSTF, and KSC to identify process of obtaining permits
- Susan Kinney reported on Jan 25 that GSFC has a current permit that would cover the transportation of the hardware
  - Permit expires September 20, 2012, Susan will work with GSFC to assure permit gets renewed
  - Permit has limits on quantity of hazardous materials
  - SSP evaluating steps to drain PODS to meet limits

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Back-up

KSC

Rev 3

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
Fabrication of hypergol and high pressure gas servicing GSE	None anticipated	None	No technical risks anticipated. WSTF has experience in hypergol GSE design and fabrication. No schedule risks identified.	Technical content not identified. Schedules provided and should not be an issue for WSTF to meet. Acceptance testing of servicing GSE should be done as part of fabrication	Technical content needs to be defined so cost estimates can be provided. Not expected anytime soon.
Perform validation and verification (V&V) of GSE that supports Ares 1 and Orion	None anticipated	None	No technical risks anticipated. WSTF has experience in hypergol GSE validation and verification. Technical risk expressed by KSC as to the ability of WSTF to perform full V&V, since MPPF is located at KSC. WSTF concurs that integrated system level validation should be done at KSC. ATP of hardware should be done at WSTF. No schedule risks identified.	Technical content not identified. Schedules provided and should not be an issue for WSTF to meet. Acceptance testing of servicing GSE should be done as part of fabrication (item above)	Technical content needs to be defined so cost estimates can be provided. Not expected anytime soon.
The cold GHe HEX performance test for fall of 2010	• Concrete pad for test article •480 V Service for booster pump •DACS •Mech system mods	$570K	Technical risks: None Identified. Schedule Risk: For testing in October, funding is needed in early March. Cost Risk: Range of estimate +/- 40%	Assumptions, flow rate calculations available for review.	Direction of work transfer to WSTF.

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Rev 3

KSC

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
OMS-RCS Decontamination	None anticipated	None anticipated	Technical Risk: None identified. Schedule Risk: DOT permit for shipping systems from KSC to WSTF needs to be obtained. 6-12 month lead time. Cost Risk: Shipping fixtures need to be identified.	TCB approval to proceed with permit application and identification of shipping fixtures. Special permit DOT-SP 5022 is in place (must re-apply before 9/30/10) to allow shipment of contaminated rocket systems.	Final approval for transfer of work to WSTF pending verification of applicability of special permit 5022 and fixturing identification.
Orion CM post-flight processing	Possible stand enclosure modifications to allow easier access to CM.	TBD	Analysis in work. KSC identified cost risk associated with maintaining 2 facilities, one at KSC MPPF and the other at WSTF. KSC identified schedule risk associated with decon at WSTF and possible post flight failure analysis at KSC O&C.	Team formed at WSTF to develop business case for CM decontamination at WSTF. Schedule for presentations not yet developed. WSTF business case to address KSC identified risks.	Business case. Schedule for presentation
Hypergol Material Compatibility Testing	None anticipated	None required, but potential for transfer of equipment for spares. Associated costs for transfer of equipment to WSTF.	No technical or schedule risks identified. WSTF has experience and facilities to perform testing. Unsure of type and quantity of hardware that could be transferred to WSTF for spares. Use same SWAG as MSFC $300K	Work transfer needs to be directed to WSTF.	Direction of work transfer to WSTF.

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MSFC

Rev 3

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
Materials Combustion Research Facility (MCRF)	None anticipated	None anticipated for transferring work to WSTF The ultimate transfer of equipment is anticipated and will have associated costs	MSFC has identified a schedule risk associated with getting high priority items processed through WSTF. Schedule risk can be mitigated by the use of Internal Task Agreements (ITA) between WSTF and the requesting organization. WSTF has identified a cost risk, since potential funding levels do not have type and quantity of work defined. Cost risk can be mitigated by the use of ITAs and will have to be negotiated to define work and funding levels. Associated costs for disassembly, packaging , shipping, and unpacking of hardware for spares is estimated (SWAG) at $300K	WSTF/MSFC have had a number of discussions since the phase II briefing at HQ. Unsure of actual funding transfer to WSTF and if MCRF would be closed down if work moved to WSTF. Good Laboratory Practice (GLP), or Round Robin Testing is performed between NASA centers, International Partners, and Industry. This practice allows test labs to assess processes to improve accuracy by comparing data to identify variances. The drivers are NASA's Materials and Processes Orgs. WSTF has historically coordinated these activities between labs. For GLP in the areas of Material Toxicity Analysis, Flammability, Ignition Mechanisms, and Volatile condensable material testing, the following labs routinely participate in comparisons: JAXA, WSTF, MSFC, JSC, European Space Agency, Russian labs, Kennedy Space center and several industry partners. The loss of MSFC will not affect this assessment	Direction to transfer work to WSTF. Determination of what funding is available to transfer. The disposition of any center operations funding to maintain the test capability and ready-to-produce costs, and the source of project work-related funding and associated numbers and types of tests

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JSC Rev 3

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
Off gassing of Flight Hardware	None	None	None	No further discussions held since Phase II presentation. No issues.	Direction of work transfer to WSTF.

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GRC

Rev 3

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
Thermal Vac Propulsion testing at Altitude Combustion Stand (ACS)	No facility upgrades are anticipated. Test specific build up is required (typical of any new test program).	No facility upgrades required.	Technical risk for achieving propellant temperatures identified in test plan. WSTF has a heat exchanger capable of achieving desired temps, but is yet unproven. Have achieved temps close to requested without heat exchanger. GRC has requested a technical risk be included addressing loss of technical competency at GRC in Space Propulsion R&T due to the consolidation at WSTF. Schedule risks to present test plan due to current test programs in TS401. FY 12 and beyond potential mitigation by moving Air Force Minuteman to TS403. Cost Risk: Cost for test specific build up (typical of any new test program) estimated at $715K (including 165K reserve), based on 100 lbf engine test program currently being performed at ACS. Increase in annual maintenance cost for PCAD estimated at $100K if AF MM program moves to TS403. Increase in DACS upgrade costs estimated at $75K (one time) if AF MM program moves to TS403. GRC has requested that a cost risk associated with researcher travel to WSTF be included to address test support if testing is moved to WSTF.	Costs based on GRC provided test plans for testing currently being done at ACS. Assumes testing done at TS401, after scheduled testing is completed in September. TS401 is used by multiple customers, which allows higher utilization of test teams and facility and allows sharing of some costs. Verified and updated delta DACS costs to PCAD if MM moved to TS403. Costs for LOX/LCH4 skid transfer to WSTF have been estimated: Disassembly at GRC 100K; Ship to WSTF 20K; Installation of both skids into WSTF test system 650K (including 100K reserve)	Discussions with GRC 1/20 identified the following concerns: 1) Capability of Hx to meet desired temperature range. 2) Schedule issues with PCAD and MM testing at TS401

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GRC

Rev 3

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
Propulsion Testing at RCL Test Stand 32 (ambient testing)	Based on past testing of 100 lbf engine, none anticipated. Propose using TS401	None	Technical Risk: Exhaust gas or unburned propellant build up in test cell igniting. TS401 is an enclosed test stand (altitude stand) will have to perform analysis of exhaust products and unburned propellant for each engine test program. Possible mitigation by running small altitude system with door to cell open to remove propellant. Installation of exhaust fans. GRC identified risk associated with not having availability of research level stand. Schedule risk: None. (no testing identified) Cost Risk: Costs for modifications to test stand associated with ambient firing in enclosed cell.	No test scheduled at GRC for RCL TS32	Decision on consolidation.

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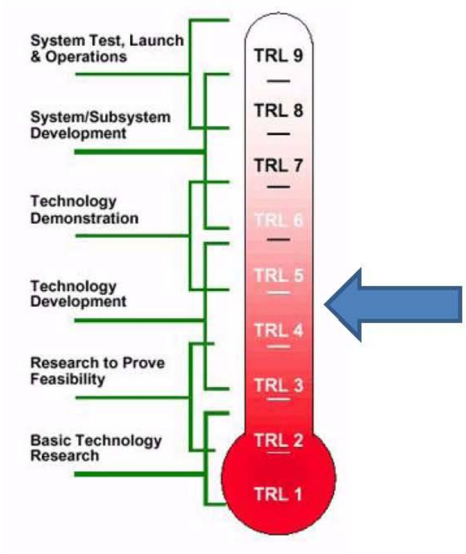
WSTF TRL Test Experience



NASA Technology Readiness Levels

- WSTF propulsion testing is generally in the TRL 4-5 and up range.
- Lower TRL tests have been performed, (eg laser ignition of LOX/Ethanol engines)
- Test stand capability does not preclude lower TRL testing
    - Lab and machine shop capability onsite to fabricate necessary hardware if needed during test program

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NASA TRL Definitions

(Source: Mankins (1995), Technology Readiness Levels: A White Paper)

Technology Readiness Level	Description
1. Basic principles observed and reported	This is the lowest "level" of technology maturation. At this level, scientific research begins to be translated into applied research and development.
2. Technology concept and/or application formulated	Once basic physical principles are observed, then at the next level of maturation, practical applications of those characteristics can be 'invented' or identified. At this level, the application is still speculative: there is not experimental proof or detailed analysis to support the conjecture.
3. Analytical and experimental critical function and/or characteristic proof of concept	At this step in the maturation process, active research and development (R&D) is initiated. This must include both analytical studies to set the technology into an appropriate context and laboratory-based studies to physically validate that the analytical predictions are correct. These studies and experiments should constitute "proof-of-concept" validation of the applications/concepts formulated at TRL 2.
4. Component and/or breadboard validation in laboratory environment	Following successful "proof-of-concept" work, basic technological elements must be integrated to establish that the "pieces" will work together to achieve concept-enabling levels of performance for a component and/or breadboard. This validation must be devised to support the concept that was formulated earlier, and should also be consistent with the requirements of potential system applications. The validation is "low-fidelity" compared to the eventual system: it could be composed of ad hoc discrete components in a laboratory.
5. Component and/or breadboard validation in relevant environment	At this level, the fidelity of the component and/or breadboard being tested has to increase significantly. The basic technological elements must be integrated with reasonably realistic supporting elements so that the total applications (component-level, sub-system level, or system-level) can be tested in a 'simulated' or somewhat realistic environment.
6. System/subsystem model or prototype demonstration in a relevant environment (ground or space)	A major step in the level of fidelity of the technology demonstration follows the completion of TRL 5. At TRL 6, a representative model or prototype system or system - which would go well beyond ad hoc, 'patch-cord' or discrete component level breadboarding - would be tested in a relevant environment. At this level, if the only 'relevant environment' is the environment of space, then the model/prototype must be demonstrated in space.
7. System prototype demonstration in a space environment	TRL 7 is a significant step beyond TRL 6, requiring an actual system prototype demonstration in a space environment. The prototype should be near or at the scale of the planned operational system and the demonstration must take place in space.
8. Actual system completed and 'flight qualified' through test and demonstration (ground or space)	In almost all cases, this level is the end of true 'system development' for most technology elements. This might include integration of new technology into an existing system.

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Appendix E. SOMD PPBE 2012 PRG – Final, dated May 7, 2010

Pre-Decisional –For Internal NASA Use Only **5/7/2010**

SOMD PPBE 2012 PRG – Final

The Office of the Chief Financial Officer (OCFO) released a draft of the Strategic Program Guidance (SPG) on April 21, 2010. This Program and Resources Guidance (PRG) provides direction to programs within the Space Operations Mission Directorate (SOMD) for responding to the Draft Agency's SPG. If you have any questions or need further clarification regarding general or specific SOMD guidance, please contact Roger Cawthon at (202) 358-4573 or Toni Mumford at (202) 358-4757.

This PRG has been updated to reflect an Agency decision made on May 4th, to transfer funds from the Mission Directorates to CAS in order to implement the facility recapitalization plan. SOMD's PRG guideline has assessed this reduction against the 21st Century Space Launch Complex.

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Pre-Decisional –For Internal NASA Use Only **5/7/2010**

PPBE 2012 Budget Guidelines

SOMD Programs are requested to submit their budget request to Headquarters (HQ) by May 6, 2010 (RPT will submit by May 10, 2010), addressing all current program requirements within the budget guidelines provided below. These guidelines are based on the FY 2011 President's Budget, at the Program level for direct funds and FTEs only (exclude labor dollars). **For FY2016, Programs should submit based upon requirements, not to exceed FY 2015 guidelines.** Unless otherwise directed, each Program must formulate an in-guide response. Any overguide issues must be clearly identified, along with a prioritized list of actions required to bring the project back within program guidelines.

SOMD FY 2012 Guidelines

RY $ in Millions	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2012 SPG Guideline Controls	**4,519.0**	**3,892.6**	**3,822.7**	**3,911.6**	**3,679.6**
Space Shuttle	905.6	64.8	0.0	0.0	0.0
International Space Station	2,606.6	2,768.7	2,893.5	2,984.9	2,962.3
Space and Flight Support	1,006.9	1,059.1	929.2	926.7	717.3
Space Communications and Navigation	424.1	446.4	450.3	460.9	460.8
21st Century Space Launch Complex	414.9	449.0	314.4	298.3	85.8
Launch Services	45.1	43.7	43.5	43.5	44.0
Rocket Propulsion Testing	37.2	35.9	35.6	39.0	39.4
Crew Health and Safety	0.0	0.0	0.0	0.0	0.0
Human Space Flight Operations	85.7	84.2	85.4	85.0	87.3

May be off due to rounding

Pre-Decisional –For Internal NASA Use Only 5/7/2010

General Guidance

All SOMD Programs should provide input for the following Decision Package, if applicable:

General Decision Package #1 (Constellation Program Transition Impacts):
The Constellation Program (CxP) had planned on using or sharing a number of SOMD program capabilities over the next several years. All Programs are asked to review their assumptions with respect to providing capabilities to Constellation, and identify and quantify potential impacts, including costs, to your Program as a result of Constellation transition. The program submit, should include a detailed description of the potential impacts (i.e., programs may be required to fund higher facility use charges due to reduced ESMD scope, workforce sharing arrangements may be reduced or voided, property use may go down or be eliminated, and funding to maintain capabilities may become at risk).

All identified budget impacts should be phased by year. The budget impacts should be presented as a delta to the baseline program or project plan. Mitigation plans should also be included. If projects anticipate they will have excess facilities or property, disposition estimates should be provided for each of the following three states:

a) Mothball
b) Abandon
c) Demolish.

Detailed definitions of states a and b are included in NPR8800.15A, however, there is no clear definition for demolish within any NASA NPR. It is suggested that these projects be coordinated with the center where the work resides, to develop estimates for design, salvage, demolition, final property restoration including environmental remediation estimates, and historic preservation impacts.

Unified Labor Account (ULA): The SOMD budget control guidelines have been reduced consistent with the Agency decision to implement a unified labor account for NASA's civil service workforce.

The PPBE 2012 process will result in Administrator decisions, regarding the appropriate size and skill mix for the NASA's civil service workforce beginning in FY 2012. This decision will be based on Mission Directorate demand estimates, center institutional forecasts, and an assessment by the Mission Support Directorate. Pending that decision, the PRG guidelines reflect a program distribution of SOMD's allocation of the costs to fully fund the current Center FTE ceilings from FY2012 through FY 2016.

Pre-Decisional –For Internal NASA Use Only **5/7/2010**

i. General Workforce Planning: All Programs (especially those with new work) must coordinate with center performing organizations to identify FTE resources. Consequently, your PPBE submit should identify coordinated efforts as to how additional FTE will be utilized; if you are unable to meet your allocated target, explain why not, and explain the mission impact resulting from accepting the increased allocation. Alternatively, if your Program requires additional FTEs, but your Center is unable to accommodate your request, provide mission impacts.

ii. The N2 database will remain open until May 6 for SOMD programs to load their PMR submit. There are two categories of FTE available for your use, ULA firm and ULA forecasted. The forecasted should include approaches for maximum utilization of CS FTEs to enhance program efficiencies and effectiveness (worksheet provided immediately below for backup). Clarification note, emphasis for this data point is on identification of new possibilities for workforce utilization.

Microsoft Office
Excel 97-2003 Wo

iii. Identification of functions currently being performed by support contractors which could potentially be considered as areas for redeployment of civil service FTE's. In making these assessments, Programs should consider and address such issues as critical skills (availability & needs), windows of opportunity for implementing the trades (both contractual and programmatic short/long term requirements), growth of in-house capability, and maximization of civil servants vice support contractors. Responses should present both advantages and possible disadvantages which could be associated with identified trade spaces. Attached Excel worksheet (under subparagraph ii, above, should be used to submit opportunities identified for increased Civil Service utilization.

iv. Address any areas outside SOMD where CS and WYE workforce could be utilized in enabling the President's new agenda (e.g., ESMD or Technology Office would be lead).

Unfunded HQs Mandates Programs are requested to notify their HQ resources counterpart if they become aware of potential unfunded mandates that could impact Programs.

FY 2010 issues should not be addressed. FY 2010 should be consistent with controls in operating and cost phasing plans. If exceptions to this policy are considered critical, please contact Roger Cawthon @ (202) 358-4573.

Guidance for loading N2 – N2 should be loaded to reflect the PMR, by 12 pm EDT on May 6, 2010. Load procurement, travel, and FTE, only (labor pricing will be completed and loaded by the Centers).

Budget Trace - Each program will submit, with their budget, a trace of all changes made from the FY 2011 President's Budget at the project level for both dollars and FTEs.

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Budget Reserves/Liens & Threats – If applicable, Programs will provide status of budget reserves and liens/threats in all years.

Budget Allocation - Programs should allocate project budgets fully to the implementing Centers for FY 2012 – 2016 based on known and probable work, and should budget for work assignments already made through the Acquisition Strategy Planning (ASP) or other decisional processes during the past year.

CAAS (DCMA/DCAA) & NCAS Program Requirements (3 products):

1) Programs are requested to identify their CAAS hourly requirements by Center, including supporting facilities (e.g., WSTF, MAF, PlumBrook, WFF, etc.) utilizing the attached worksheet, below. This data is necessary to ensure all requirements are funded and to support OCFO's annual negotiation of CAAS rates with DCMA and DCAA.

2) In addition, consistent with the Agency guidance for SMA data, the Programs' are to load their estimates into the SAARIS (more details should be issued by the MSD PRG—SMA functional section) by June 10, which will allow the SOMD to concur by the Agency deadline of June 15th.

3) Programs are also requested to identify their NCAS/SMA requirements using the NCAS worksheet below and provide to SOMD no later than June 10, 2010, which will enable SOMD to validate these requirements by June 15th as required by SPG.

If additional clarification is required to complete the three products, please contact Roger Cawthon @ (202) 358-4573 or Mike Milsted @ (202) 358- 4728.

SOMD CAAS 2012 Rqmts,2 SOMD NCAS 2012 Rqmts,12

Information Technology (IT) Services —2011 PPBE decisions and impacts for 2012:

Programs need to ensure new IT systems being brought into operation during this time frame have C&A costs budgeted for based on the unit cost table. Also, any additional required work that must be performed by third-party C&A providers as part of normal annual system control reviews or other related work should also be budgeted for. Reference the price table below (SPG Draft-dated 4-21-2010):

- Each Mission Directorate and Mission Support Office should plan to budget for certification services using the pricing table established for FY 2010 (listed in Figure D.1). The OCIO has completed negotiations with the SEWP Contract at GSFC for certification services in an effort to gain better pricing efficiencies for certification services and in doing so the out year pricing information is listed below.

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NASA SEWP IV Contract NNG07DA21B					
RMS C&A Support for Moderate Systems					
Product ID	Description	Unit Cost	Qty	Ext Amount	Device Count
RMS-M-TS-1	SecureInfo RMS on-going technical support to maintain the RMS product for Moderate Category systems with up to 25 devices. This product includes expert RMS technical support including data collection, configuration and data entry within the RMS product. SecureInfo will reconfigure each Moderate System RTM and input applicable artifacts into the RMS system as collected from NASA system owners. Support units are based on system device counts as received from NASA system owner (minimum purchase of 2 units).	$12,000	1	$12,000	25
RMS-M-TS-1A	Additional unit of SecureInfo RMS Moderate Category System on-going technical support support for up to 25 devices above minimum purchase	$6,000	1	$6,000	25
RMS C&A Support for High Systems					
Product ID	Description	Unit Cost	Qty	Ext Amount	Device Count
RMS-H-TS-1	SecureInfo RMS on-going technical support to maintain the RMS product for High Category systems with up to 25 devices. This product includes expert RMS technical support including data collection, configuration and data entry within the RMS product. SecureInfo will reconfigure each High Category System RTM and input applicable artifacts into the RMS system as collected from NASA system owners. Support units are based on system device counts as received from NASA system owner (minimum purchase of 2 units).	$13,000	1	$13,000	25
RMS-H-TS-1A	Additional unit of SecureInfo RMS High Category System on-going technical support support for up to 25 devices above minimum purchase	$6,500	1	$6,500	25

Figure D.1 – SEWP Certification Services Pricing Tables

In addition:

- Programs need to ensure IT system C&A renewals that are expected to occur within this PRG's time frame are budgeted for. You may consider using Extension of Authority to Operate (EATO) as provided for by NASA IT Security Handbook ITS-HBK-0006 to delay renewing a C&A ATO for up to 6 months. One reason for doing this would be to delay some IT system C&A renewals in cases where you have a large number of systems needing renewals at the same time, but the C&A costs must still be planned for if the renewal still falls within the planning timeframe of this PRG.

- The Shuttle Program should plan to use Extension of Authority to Operate (EATO) as provided for by NASA IT Security Handbook ITS-HBK-0006 for all Shuttle IT systems that are retiring after Shuttle Program shutdown. Extensions of the current C&A Authority to Operate (ATO) of up to 1 year is provided for in the policy because those systems are being retired. IT systems that are still expected to be running after the 1 year extension may have to be re-certified at that time and should be planned for if those renewals will fall within the time frame of this PRG, though a blanket waiver or further extension will be pursued for these particular IT systems before the 1 year extension period is up.

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For center specific questions, please contact your Center CIO Office. For general program questions, please contact Mr. Joseph Watson at 202-358-1172 or Mr. Jim Cassidy at 202-358-4606.

Construction of Facilities

NASA will renew and modernize its facilities to sustain its capabilities to meet current and future mission requirements, and to accommodate those capabilities in fewer, more efficient facilities. The Agency has made a decision to renew its facilities using a slow and steady approach to reduce, replace, and consolidate NASA's aging facilities with sustainable facilities.

As part of the FY 10 PPBE process Mission Directorate liens were established to fund the programmatic portion of the Agency's recapitalization requirements. These liens have been revised as shown in the Agency SPG to include FY 2015 and FY 2016 requirements, reflect subsequent Agency decisions to reduce and/or adjust liens, and to include Space Technology. Mission Directorates are asked to address the impacts of funding these liens as part of their PAA submittal. This PRG has been updated to reflect an Agency decision made on May 4th, to transfer funds from the Mission Directorates to CAS in order to implement the facility recapitalization plan. SOMD's PRG guideline has assessed this reduction against the 21st Century Space Launch Complex. The impact of this change will be worked within SOMD during the PAA process.

Human Space Flight Capabilities Update:

SSP, ISSP, Exploration Offices, Chief Technology Officer, and Institutional Offices (Centers and Headquarters) plan to meet at KSC for the integrated Human Space Flight Capabilities (HSFC) Forum #4. **The HSFCF #4 will kickoff with Phase A scheduled at the KSC on May 10-12, 2010, followed by a Phase B targeted for mid June.** Attendance will be restricted, but inclusive of necessary stakeholders and decision makers. The purpose of this meeting will be an analysis of the total capability supply affected by the cancellation of Constellation. Phase A will be a data gathering opportunity as it will review the status of human spaceflight capability gaps from previous years and will survey new gaps opened as a result of the proposed cancellation of Constellation. Details of the HSFCF #4 will be issued under separate letter.

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White Sands Test Facility (WSTF) Decision Package

WSTF Decision Package:
In the last half of CY 2009, SOMD conducted an assessment of the WSTF core capabilities. The team developed options and plans, to correctly size the WSTF for expected future work. The following six actions were recommended, in order to help preserve the minimum infrastructure and skill sets needed for future operations at WSTF.

1. Close the MSFC Materials Combustion Research Facility (MCRF) and transfer all functions, testing, and related funding to WSTF.
    a. MSFC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD Human Space Flight Operations (HSFO) for WSTF operations.

Materials Combustion Research Facility (MCRF)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
MSFC MCRF Capability O&M	$ 155	$ 160	$ 166	$ 173	$ 179	$ 186	$1,019	*Utilized MSFC estimates and inflationary assumptions*

    b. Equipment and test hardware will be evaluated for utilization as spares and relocated under separate action
        i. SOMD / ESMD provide $300k for dismantle and shipping of spares to WSTF
    c. MSFC to maintain Environmental Gas Lab (EGL) for sampling and testing center-wide propellant and pressurant distribution systems, clean rooms, and flow benches.
        i. MSFC to evaluate transferring EGL to a different location on site with the goal to close and demolish Building 4623
            1. MSFC to report to Transition Control Board within 6 months on the ability to close and demolish Building 4623

2. Transfer the KSC Hypergol Material Compatibility Testing Lab functions, testing, and related funding to WSTF.
    a. Equipment and test hardware will be evaluated for utilization as spares and relocated under separate action
        i. SOMD / ESMD provide $300k for dismantle and shipping of spares to WSTF

3. Close the GRC Altitude Combustion Stand (ACS) and transfer all functions, testing, and related funding to WSTF.
    a. GRC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Thermal Vac Propulsion testing at Altitude Combustion Stand (ACS)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
GRC Capability O&M	$ -	$ -	$ 184	$ 189	$ 195	$ 201	$ 768	*Updated 2/9/2010 - GRC O&M estimate w/ inflation*

    b. SOMD / ESMD provide $800k to dismantle and relocate Propellant Conditioning Skid and other items for spares from GRC ACS and RCS 32 to WSTF
    c. GRC to seek Agency Strategic Institutional Investment funds to demolish ACS.

4. Close the GRC RCL Test Stand 32 and transfer all functions, testing, and related funding to WSTF.
    a. GRC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Propulsion Testing at RCL Test Stand 32 (ambient testing)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
GRC Capability O&M	$ -	$ 134	$ 142	$ 146	$ 151	$ 155	$ 729	*Updated 2/9/2010 - GRC O&M estimate w/ inflation*

    b. GRC to seek Agency Strategic Institutional Investment funds to demolish RCL-32.

5. Transfer of the JSC Flight Hardware Offgassing testing and related funding
    a. JSC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Off gassing of Flight Hardware								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	*Notes*
JSC Projected Testing	$ 70	$ 73	$ 75	$ 78	$ 81	$ -	$ 378	*Assumes test rate of ~20 items/yr. Doesn't include O&M*

6. All Center's perform excess fabrication, testing, cleaning, machining, environmental, calibration, and component processing that falls within WSTF area of expertise at WSTF prior to outside vendors
    a. WSTF report semi-annually to the Transition Control Board on extra work being transferred
    b. Centers report yearly on transferred work and planned activities to be sent to WSTF

SOMD will collaborate with ESMD to implement these recommendations, and transfer the necessary funding during PPBE 2012. Consistent with the study recommendation, it is understood that additional actions will be necessary, to ensure that WSTF is funded at the recommended, minimum capabilities level. SOMD, ESMD and OPII will work jointly with WSTF to close this gap.

Michoud Assembly Facility (MAF) Operations Guidance/Decision Packages

MAF Transition of Operations and Maintenance (O&M):

A specific budget guideline is not provided in the PRG. SOMD and ESMD will jointly review MAF requirements and plan to establish a baseline budget during the PPBE 2012 process. MSFC is requested to provide a detailed cost estimate consistent with all Program requirements, and include all funding sources. MSFC should work with the SSP and Exploration Offices to ensure that they have the most current transition and utilization schedules, particularly for SSP personal property. The baseline submits should provide a detailed cost estimate and basis of estimates at the lowest WBS level available. The budget submit should include:

a. FTE/WYE
b. Square foot utilization
c. Funding gap
d. Lab capability utilization plans and cost to maintain.
e. Facility consolidation opportunities
f. Identify tenant reimbursable assumptions (approved tenants).

g. Identify potential new tenant reimbursable assumptions.
h. Identify options to reduce the baseline cost estimate, including deferred maintenance or construction, reduced services or delayed capabilities.

For planning purposes, prepare 3 additional MAF decision packages:

MAF Decision Package #1 - Assume that detailed utilization plans are unavailable; MSFC should develop planning estimates to operate MAF in a "commercial tenant ready" capacity for FY 2011 and FY 2012, and subsequently reactivated. The MAF production environment would be available to perform NASA projects and/or NASA technology R&D. Provide FTE and WYE impacts; discuss impacts to tenant agreements, and the state of Louisiana. Provide assessment of skills impact, property disposition planning, facility maintenance and utilization, and any contractual issues.

MAF Decision Package #2 - Assume that detailed utilization plans are unavailable; MSFC should develop planning estimates to operate MAF in a "commercial tenant ready" capacity for FY 2011, and a "facility minimal maintenance" capacity for FY 2012-2015, and subsequently reactivated. Provide FTE and WYE impacts; discuss impacts to tenant agreements, and the state of Louisiana. Provide assessment of skills impact, property disposition planning, and any contractual issues.

MAF Decision Package #3 - MSFC should provide an estimate to operate MAF in a "commercial tenant ready" capacity for FY 2011 and a "facility minimal maintenance" capacity for FY 2012 and subsequently placed in a mothball status. Use NPR 8800.15A, definitions baseline for this estimate. Selected excerpts from NPR 8800.15A, are identified as follows;

- Mothballed. A condition where a facility has been deactivated and appropriate maintenance measures have been taken to prevent deterioration of its vital or essential systems or placed in protective storage. Higher first year costs would be expected because of preparations for mothballing, but future annual costs should be significantly lower due to reduced maintenance and repair requirements. Total time to deactivate and then to reactivate the facility, including the mothballed period, is expected to exceed 12 months.
    - Utility systems and collateral equipment have been shut down and properly prepared for long term inactivation without significant deterioration. Selected systems should be kept in operation and inspected, such as cathodic protection systems.
    - Facility interior has appropriate environmental control to prevent significant deterioration

For information only, provide a description and status of probable non-NASA work which may be secured for MAF, an estimate of the likelihood of bringing that new work to MAF, and the potential external annual revenue to offset MAF O&M from those sources. What are the potential cost implications to truly making MAF a multi-use facility? Is there an option of providing MAF facilities as a medical treatment facility for local businesses?

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Space Shuttle

General Guidance

With the 2012 budget the Space Shuttle program (SSP) should be well into transition and closeout. If flights slip from FY 2010 to FY 2011 some funds and flight work will move. This budget should describe plans to accommodate this delay. The approved transition and retirement plan is to be completed during 2012. Detailed budget planning and work plans should be developed and provided to accomplish these activities. Specifically work plans for Orbiter disposition and property disposition should be completed and used to refine FY 2012 budget. Discussion on former SSP civil service funding and transition of former SSP FTE should be provided.

Severance and Retention (S&R)

Provide the updated Severance and Retention (S&R) cost estimate as a separate product. Include the following:

- Content currently funded in the SSP baseline
- Threats
  - ➢ Identify the estimated new obligation authority (NOA) required for the pension liability issue with United Space Alliance (USA).
- Estimates that are partnered and negotiated with the contractors vs. contractor to government estimates not yet agreed

Decision Packages - Operations

Decision Package #1: Provide data on where SSP civil service FTEs and Center on-site support contractor WYEs who charged to SSP in FY 2010 will transition to after SSP retirement. For the on-site support contractors, emphasis should be to capture those "predominately" supporting SSP and ISS. At a minimum, please provide % the company has work remaining versus % layoffs. Data should be provided by Center, by fiscal year, for FY 2010 – FY 2012, per the following guidelines:

- Civil Servants
  - Data call should focus on science and engineering FTEs charging at least 25% of time to SSP in FY 2010. Administration FTEs transferred to Center CM&O in FY 2010 should also be included as well. Data should provide the assignments for these FTEs, by Center and by fiscal year, from FY 2010 – FY 2012, according the following categories:
    - ▪ FY 2010 SSP FTEs assigned to SSP T&R
    - ▪ FY 2010 SSP FTEs assigned to other SOMD work
    - ▪ FY 2010 SSP FTEs assigned to ESMD-sponsored work
    - ▪ FY 2010 SSP FTEs assigned to other Directorates-sponsored work (cite each directorate as applicable)
    - ▪ FY 2010 SSP FTEs assigned to Center CM&O
    - ▪ FY 2010 SSP FTEs not assigned
    - ▪ FY 2010 SSP FTEs retired or resigned
- On-site Support Contractors

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- Data call should focus on on-site support contractor WYEs supporting SSP in FY 2010. Data should provide information for these WYEs, by Center and by fiscal year, from FY 2010 – FY 2012, according to the following categories:
  - FY 2010 SSP on-site support WYEs assigned to SSP T&R
  - FY 2010 on-site support WYEs assigned to other SOMD work
  - FY 2010 SSP on-site support WYEs assigned to ESMD-sponsored work
  - FY 2010 SSP on-site support WYEs assigned to Center CM&O
  - FY 2010 SSP on-site support WYEs assigned to other Directorates-sponsored work (cite each directorate as applicable)
  - FY 2010 SSP on-site support WYEs not assigned (includes employees laid off)

Transition and Retirement (T&R)

Overview
The goal remains the same: to plan the lowest cost and most efficient transition and retirement of the Space Shuttle. The SSP should integrate the total program plus institutional requirement to update and implement the approved PPBE 2011 plan. SSP will provide the integrated plan because the SSP possesses the most expert and comprehensive knowledge of the Space Shuttle physical systems. SSP should provide guidelines to the institutional offices of KSC, JSC, MSFC, SSC, and DFRC so that the specific institution tasks within the T&R Plan scope are updated with refined estimates.

- T&R plan schedule must match the Operations manifests schedule, including each Orbiter's last mission date (or LON readiness release date). Plans, schedules and estimates need to be synchronized to the Space Shuttle budget FY 2011 manifest included in this guidance. This submit should accomplish all personal property work, including safing, and the unbudgeted threat of display preparation and ferry of Orbiters, no later than the end of FY 2012.
- The estimates provided should be based on the content that was previously budgeted on the basis of the Exploration Program of Record. A separate decision package will be requested for the delta costs that will be incurred associated with the cancellation of the CxP, and the initiation of the 21st Century Space launch Complex program and the start of new programs such as flagship technology demonstrators that will be required for transition.
- Identify as a special data product the labor and cost for decontamination and safing of hazardous Space Shuttle personal property and real property.

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- Provide update to the following "OMB threat cost" format for SSP T&R threat plus Agency T&R threats:

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Space Shuttle Transition and Retirement Threats

9/22/2009

SSP T&R Level 1		Threats	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	
SSP	1	Recordation	0.5						0.5
SSP	1	Records Disposition & Imagery	2.7	5.7	2.9				11.3
SSP	1	Artifacts Identification and Disposition	4.4	5.6	0.0				10.0
SSP	1	Information Technology (IT) Disposition	3.0	1.0	0.0				4.0
SSP	1	Aerojet & Moog Solid Rocket Booster (SRB)		5.0	5.0				10.0
SSP	1	Accelerated SSME Property Disposal	3.0	0.6	-2.8				0.8
			13.6	**17.9**	**5.1**	**0.0**	**0.0**	**0.0**	**36.6**

Agency T&R	Threats	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	
Agency	Orbiter Display Safing Prep/Ferry		47.0	13.0				60.0
Agency	Residual Retirement Activity				30.0	11.0	10.0	51.0
Agency	SSME Display Preparation	1.0	1.0					2.0
		1.0	**48.0**	**13.0**	**30.0**	**11.0**	**10.0**	**113.0**

-Agency T&R threats are not included as a part of the Space Shuttle Threats list

Detailed T&R Guidance

Personal property disposition and disposal estimates should be provided in detail, with clear justification for the cost and labor drivers for contractor preparation and reporting of personal property for turn-in to the institution or turn-over to DCMA. If personal property disposition costs were based on assumed offsets from sale or scrap value of excessed property, state the amount of the offsets originally assumed, as well as any changes to those assumptions, by individual contract and location. Personal property cost should include any costs to provide information required by Office of Infrastructure to conduct "potential artifact prescreening" or GSAXcess sale.

Identify the costs and labor estimates for property decontamination, safing or modification/destruction, as required by the hazard levels and "Special Handling" determinations made by the Program in response to Office of Infrastructure policy. Identify the cost and labor by major groupings of similar property (e.g., the lower levels in the T&R WBS). The Basis of Estimate should identify the assumed disposition path for the personal property (i.e., transfer to Constellation or ISSP or a different NASA funded program, donation, sale or scrap).

The program shall identify and estimate the costs for the transfer of all personal property to the CxP or institution that has partnered with the SSP. All personal property which is not partnered for transfer should be budgeted for excess. If the SSP identifies specific personal property that may not have been partnered to date with the partnering organization but the program has concluded would be transferred at some point, the delta cost avoided from the submit if this personal property were actually transferred in instead of excessed should be identified for information purposes.

SSP should not provide Michoud Assembly Facility (MAF) "floor space" costs for disposition of SSP personal property in FY 2011 or FY 2012. SSP should budget to use the MSFOC to dispose of excess External Tank personal property which is not accepted for transfer by Constellation (for project use) or by the MSFC MAF office (to operate the MAF).

Additional T&R Guidance

SSP is to provide the updated requirements to the PPBE 2011 T&R plan scope with the following changes:

a. Add facility historical recordation costs for those facilities designated to be demolished by the institution after program end, which are also eligible as national historic properties. This list of eligible properties is included as Figure 2.
b. The "Orbiter Display Preparation" threat should be based on ferrying two Orbiters to museum destinations; however, the additive cost of ferrying the third Orbiter should also be included.
c. Costs and labor for Information Technology transition should be populated into the existing work breakdown structure (WBS) elements (i.e., personal property, records or software) instead of generating new WBS element(s). The aggregated estimate can also be displayed for information purposes by summing WBS elements to show the revised cost estimate.

The SSP should review and update the Level 1/Agency T&R Threat Summary as provided in Figure 3, and update the Threat estimates for each Threat and each fiscal year. The Threat for Display Preparation/Ferry of Orbiters should include costs for Space Flight Crew Operations (SFCO) (Shuttle Carrier Aircraft) and Shuttle Landing Facility (SLF) utilization.

__**Decision Packages - T&R**__

T&R Decision Package #1: Provide an update to the work plan for display preparation for the three Orbiters and the costs to ferry two Orbiters to remote locations for display. The updated estimates should be based on:

- Progress defining Orbiter End State Requirements and the Safing/Display preparation and ferry flight operations.
- Defining the values for "public safe" chemical exposure based on information provided by the Department of Defense, the NASM, and the NASA Office of Chief Health and Medical Officer.
- SLF at KSC O&M for post-FY 2010 SCA/Orbiter ferry needs to be included in FY 2011 & FY 2012. However, the SSP should work with KSC to reduce annual SLF O&M to under the $1.6M/year estimate, considering that OPO/L&L will use the runway to only 2 or 3 times for Orbiter ferry flights over 2 years.
- FCOD costs and labor to enable and conduct the ferry flights should be included.

- As a separate estimate, provide cost and labor to transport the third Orbiter from KSC to a separate public museum/facility elsewhere in the United States.
- As a separate estimate, provide cost and labor to transport the Approach and Landing Test (ALT) Orbiter Enterprise from the NASM Udvar-Hazy facility to a different American museum located in the United States. Assume that Orbiter Discovery is safed, prepared for display and flown to Washington-Dulles International Airport, and transported to the NASM Udvar-Hazy facility. The Orbiter Enterprise would be transported from the Udvar–Hazy facility as part of the Orbiter Discovery delivery to the Air & Space Museum.

T&R Decision Package #2: Provide cost and work plan to prepare the assembled SSME Block II (flight configuration) engines, and their associated "flight" System Replaceable Units, Line Replaceable Units (SRUs/LRUs), for transport from KSC to museums for display, assuming that the SSMEs are not included with the three Orbiters, and are not used in follow-on NASA programs. Assume a decision would be made on the date of the last Space Shuttle mission to excess the SSMEs as museum displays or move them to Centers for engineering use. No assembly of flight components should be included, simply an estimate for provision of the parts, SRUs/LRUs, assembled engines and tools.

T&R Decision Package #3: As a separate exercise develop the costs and work plan for holding the remaining SSME Block II flight assets (~14 engines) in flight ready configuration. Develop plans and costs for using several of these engines in a technology development and skills expansion program. Develop plans and costs associated with an engine test program. Specifically this program is to look at engine design margin and should include test to failure to determine effectiveness of the advanced health monitoring systems on the engines. Also investigate ways to improve performance or lower SSME manufacturing costs through reductions in requirements. This Test program DP should be provided for information, and will be considered an overguide or part of NASA technology innovation. As part of the plan, identify partners and teaming arrangements to reduce costs; these aspects may greatly affect whether the DP is accepted.

T&R Decision Package #4: Construct an estimate working with KSC to demolish the three Mobile Launch Platforms (MLPs). Document the technical rationale for demolition instead of long term abandonment, and identify the environmental and technical schedule drivers for the demolition. MLPs are not eligible for the NASA real property demolition list, and originally they were to be abandoned at the park sites if not needed by the Constellation Program. As part of this DP, investigate if the KSC visitor center has any need for a MLP, and if so the cost (or cost avoidance) of maintaining one MLP as a visitor exhibit.

T&R Decision Package #5: SSP T&R must budget for disposition and excess of all ET personal property which is not accepted by Constellation for transfer, or MAF operations personal property which was not accepted by MSFC MAF Office for transfer. Some personal property may still be under evaluation by Constellation for transfer but has not yet been accepted. Please provide annual count of line items and delta disposition cost to excess this "under evaluation" personal property, for information only.

T&R Decision Package #6: Provide a set of estimates based on the impacts associated with the cancellation of the Constellation program and the initiation of the 21st Century Space launch Complex program and the start of new programs such as flagship technology demonstrators that will require property or facilities to be transitioned from SSP.

Deliverables

Deliverables should include the following:

1. An update to the Transition and Retirement PPBE 2011 Plan including annual costs, Civil Service FTE and WYE on Format 1. The information should be shown by SSP Element, by Location (NASA Center or Contractor Site), and by Major Contractor. If the updated requirement has costs in later years, show each year's costs. This data should be provided according to the SSP T&R Work Breakdown Structure (WBS) used for PPBE 2011 and provided as Figure 1 for FY 2010-2012. These costs should be segregated by program direct vs. institutional requirements.

2. Update the list of T&R Threats and provide detailed rationale for each threat including any differences in work approaches or basis of estimate among the institutional offices at KSC, JSC, MSFC, SSC and DFRC. The SSP level plus Agency level format is provided on page 2 of the T&R section)

3. The updated Personal Property Disposition Plan should be provided by year, by SSP Element, by Location (NASA Center or Contractor Site), and by Major Contractor. Just as in PPBE 2011 guidance, the number of line items of personal property at each section each year should be sub-identified as to transfer versus excess, and excess should be sub-identified into three categories:

   (a) Excess/Dispose Immediately (to clear space for the Constellation Program, or to donate any identified potential artifacts);
   (b) Turn-Over to Center – turn safed/decontaminated personal property into Center for eventual disposition as resources allow.
   (c) Turn-Over to Contractor or DCMA – turn safed/decontaminated personal property into DCMA at Contractor or vendor site for disposition at contractor/vendor/supplier Site.

   For each category, the location sites should explicitly identify Michoud Assembly Facility (MAF), NASA Shuttle Logistics Depot (NSLD), Palmdale, Santa Susana Field Laboratory (SSFL), White Sands Test Facility (WSTF), Dryden Flight Research Center (DFRC), Pratt & Whitney Rocketdyne - Canoga Park, Pratt & Whitney - West Palm Beach and Alliant Techsystems Inc. (ATK) locations.

4. SSP should update the PPBE 2011 Records Management phasing plan to show progress on records management (such as yearly numbers for archive of documents or destruction of documents). The units (i.e., boxes of documents or number of documents) should be identified. The phasing format should be that used for Records in PPBE 2011 Revision 1.

International Space Station

General —For budget planning purposes, the ISS program should assume sustained operations through FY2020 with Program life extended indefinitely. ISS should include the baseline activities to support the proposed COTS and future commercial crew vehicle(s) as an extension of the normal work performed for crew and cargo transportation.

ISS Crew Cargo Services Assumptions - The U.S. contribution for crew transportation is assumed to be Soyuz until domestic commercial providers for crew transportation are expected. Provide the date that commercial crew transportation must be available based on the current authority to purchase Russian vehicles (Iran North Korea Syria Nonproliferation Act) and the required overlap needed with Soyuz to mitigate program risk. The baseline budget should include updated budget estimates based on the Cargo Resupply Contract (CRS) awards, updated Soyuz costs, and projected estimates to purchase commercial crew transportation. Cargo transportation should include transportation for National Laboratory as part of the ISS Full Utilization Plan (see below). National Laboratory requirements should be coordinated with the Assistant Associate Administrator for ISS before submission.

ISS Enabling National Laboratory Plan - Develop a detailed plan to support enabling of ISS as a national laboratory. The plan should include specific tasks and their associated budgets phased by year. The plan must fit within the targets below and should be coordinated with the Assistant Associate Administrator for ISS before submission. For the NatLab Cargo Transportation line, funding in the Space Program Integrated Contract Environment (SPICE) for national laboratory cargo transportation should be book kept in a unique WBS within the ISS Crew Cargo Services project. For the NatLab Enabling Function line, subcategories of cost should include, at a minimum, requirements for: (a) Space Life Sciences Lab Facility O&M; (b) payload integration and ops support; (c) any required payload apparatus duplication, replacement, refurbishment, and recertification; (d) rapid sample return technology DDT&E; and, (e) special studies, outreach communications and advisory committee support.

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Enabling National Laboratory	*36.100*	*64.000*	*106.500*	*164.600*	*197.000*
National Laboratory Enabling Utilization	11.600	17.400	13.600	14.100	20.000
National Laboratory Cargo Transportation	24.500	46.600	92.900	150.500	177.000

ISS Decision Package #1: The program will provide an analysis of the impacts (budget and technical) of Program life extension beyond 2020. This should include technical issues and concerns, decision points, and phased ROM estimates for any identified cost impacts.

ISS Decision Package #2: Develop a detailed plan to "increase ISS functionality" with specific tasks and associated budgets phased by year. Tasks identified should meet one or more of the following criteria:

- Benefit future human spaceflight programs

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- Lower ISS operations costs
- Reduce demands on crew time
- Remove constraints that currently impact ISS operations
- Lower ground-based mission operations costs, potentially by initiating improvements based on work from a broad variety of NASA centers (including ARC and JPL) and in industry
- Mitigate capabilities lost when the Shuttle retires
- Increase ISS capabilities
- Improve ISS safety (e.g. MMOD mitigation)

Each task should identify which criteria it meets and should include a written justification. The overall plan should be prioritized and must fit within the targets below:

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Functionality Increase	62.700	145.500	302.000	351.000	401.500

ISS Decision Package #3: Develop a detailed plan for scientific and engineering research with tasks and associated budgets phased by year. At a minimum the plan should include: (a) support for planning and implementation of ERTD projects that will be selected during FY 2010 for execution beginning in FY 2011, and (b) completion of biotechnology and polymer research apparatus technologies previously suspended; and, (c) identification and development of on-orbit characterization technologies to minimize future research downmass requirements; (d) Competitive grant funding for basic science activities on the ISS; and (e) activities in the biological and physical sciences. Each task should include a written justification. The overall plan should be prioritized and coordinated with the Assistant Associate Administrator for ISS before submission and must fit within the targets below:

	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
ISS Research	*50.000*	*50.000*	*50.000*	*50.000*	*50.000*

ISS Decision Package #4: Identify and quantify potential impacts to ISS as a result of Constellation transition. The submit should include a detailed description of the potential impacts (i.e., facilities, workforce, capabilities) along with the budget impacts phased by year. Mitigation plans should also be included. ***(Note: This is same requirement as General Decision Package #1; only one submission from ISS is required.)***

ISS Decision Package #5: The program will submit a detailed plan on Lithium Ion battery development. The plan should leverage off of the work being done by the auto and transportation industry.

Space Communications and Navigation

Specific budgetary guidance will be submitted to the projects separately by the SCaN Headquarters Program Office.

SCaN Unique Guidance

NASA Integrated Services Network (NISN)

The NISN budget will reside in SOMD; however, the management of the budget will be implemented by the Office of the Chief Information Officer (OCIO). Please refer to the OCIO section for additional information and guidance.

Tracking and Data Relay Satellite (TDRS) Continuation (TDRS-M and TDRS-N)

The SCaN Program Office shall address the need date and budget required for continuing the TDRS fleet replenishment beyond the approved TDRS-K and TDRS-L acquisition. SCAN will address at least three scenarios:

1. Continuation of current partner relationships (similar to the K/L acquisition);
2. Only NASA as payer
3. Assume an Optical Communications Project payload is attached to TDRS M/N

For the first two scenarios, consider the impact to long-term reimbursable and TDRS System (TDRSS) reliability, as well as the availability to support NASA missions.

Optical Communications

The SCaN Program Office shall submit a decision package (DP) on the continuation of Optical Communication beyond the first demonstration flight manifested on the Lunar Atmosphere and Dust Environment Explorer (LADEE). The Space Operations Mission Directorate (SOMD) will coordinate the findings of the DP with the Space Technology Program Office.

Spectrum Management

Spectrum Management ensures the availability and allocation of radio frequency spectrum for all Agency programs to support the operation of navigation systems, space and ground based radio transmission, and mission sensor operations. SCaN shall address and understand both center and agency spectrum how as it relates to NASA Policy Directive (NPD) 2570.5 Subject: NASA Electromagnetic (EM) Spectrum Management.

21st Century Space Launch Complex

This PRG has been updated to reflect an Agency decision made on May 4th, to transfer funds from the Mission Directorates to CAS in order to implement the facility recapitalization plan. SOMD's PRG guideline has assessed this reduction against the 21st Century Space Launch Complex.

The President's FY 2011 Budget initiates a new program to modernize the Florida launch range and transform the Kennedy Space Center into a facility that is worthy of this Nation's 21st century space programs. A SOMD working group supporting the Budget Rollout Integration Team (BRIT) is currently drafting a plan that will outline our activities. The group is in the process of identifying a point of contact from the FAA and the Air Force (45th Space Wing) to join the team. The goal is to initially gather as much input from NASA programs, the Air Force/DoD, other Government Agencies with space programs, the FAA, and the Commercial space sector to identify strengths and weaknesses of the current state of the Florida launch range. Several targets of opportunity will include:

- Payload/spacecraft development and processing capabilities,
- Launch vehicle processing capabilities,
- Range safety capabilities and considerations,
- Launch vehicle/spacecraft manufacturing capabilities and needs, and
- Environmental remediation.

The team developed an initial plan and reviewed the plan with OSTP/OMB on April 8, 2010, Once NASA confirms our interpretation of OSTP/OMB requirements, the agency will go out with a Request for Information (RFI) asking for input on the areas identified above – targeted for May or June. NASA will review input from the RFI and convene a Government/Commercial/Civil Space Vehicle Processing and Launch forum. The forum will discuss the information gathered through the RFI and to begin to prioritize modernization projects that will start this program down the road toward meeting stakeholder needs.

The biggest challenge is to identify sufficient content to initiate projects in FY 2011 that will utilize the proposed budget as received in the PBS 2011 to support the mark-up process for the FY 2011 appropriation bills. There will be a need to deliver an initial data set on a timely basis which may not have initial input from all stakeholders for a complete project prioritization. Although the list of range and launch modernization projects is growing, the input from all stakeholders and the determination of economic benefit will drive the prioritization of projects and will work with SOMD to provide updates at an appropriate time.

SOMD made the decision to convert the Constellation Space Transportation Office and staff into the lead office to form the foundation for this effort.

In addition to the deliverables being worked by the planning team, the following additional Deliverables are required:

- May 6 – Initial project list for FY 2011 and identify project goals for succeeding years
- June 1 – Initial project list for FY 2012-2015

Launch Services

GENERAL GUIDANCE:

Proposed changes from this guidance must be supported in detail. Procurement, travel, labor, civil Service FTE, on site WYE and off-site contractor WYE line items are to be addressed. Direct funding adjustments can include zero-sum transfers between budget lines, augmentations, re-pricing, etc. Should an overguide request be submitted it will be reviewed by the Launch Services Program (LSP) Program Manager to determine whether or not it will be submitted to SOMD.

SPECIFIC GUIDANCE:

Several manifests will be used during the various phases of the budget process and are listed below.

- The approved Flight Planning Board (FPB), manifest is attached (Attached ATL & BTL manifests shall be loaded into Clearinghouse and emailed separately). The FPB manifest includes LSP near-term missions that are on contract.
- An above-the-line (ATL) manifest is attached. An updated above-the-line manifest will be issued at a later date under separate cover, if required. The above-the-line manifest is a coordinated effort between the LSP Program Business Office, SOMD Launch Services Office, Spacecraft customer, and Mission Directorates' identifying manifest requirements for Launch Services. The PPBE manifest is used as a mechanism to align the current FPB manifest with the President's budget. For the purposes of the PPBE, it will replace the FPB manifest.
- A below-the-line (BTL) manifest is attached. The below-the-line Launch Services Manifest represents potential mission requirement changes and specific requests from spacecraft projects, such as the Decadal survey.

All programs/projects requiring NASA-acquired launch services will clearly identify the services required by performance range/vehicle class and target launch readiness dates. Also, provide any identified mission-unique, special scheduling, and any below-the-line submission requirements.

The LSP, hosted at KSC, will identify any potential delegations to other Centers. The LSP Program Business Office should identify any required support from other Centers and identify the resources necessary to meet Agency requirements. Budget requirements to performing Centers, resident offices, and contractors shall be issued by the LSP Program Business Office consistent with the PRG Guidelines.

The LSP is expected to provide an achievable in-guide program budget submit. Any de-scoping or re-phasing issues required to remain within guideline should be clearly stated. The program and schedule impact of adhering to the guidelines must be addressed for each project that is requesting over guideline funding. Resources required in excess of funding guidelines should be described in detail, as well as the impact of not receiving the proposed over guideline amount.

Center cost submissions will not exceed their total available obligation authority. All Center submissions should trace back to the official LSP Office official issued PRG and not to any Center generated guidelines. Center submits should include FY 2011-2016 annually, and total columns on each format. Electronic copies of each Center's submit shall be provided to the LSP Program Business Office in addition to the data entered into the agency's budget system.

Science Mission Directorate (SMD) – Launch Services

The guideline provides funding for Launch Services for the SMD missions identified by planning launch date and performance range/vehicle class in the enclosed Launch Services above-the-line manifest. LSP is to provide a launch service funding profile for each mission to include basic launch services, estimate for mission-unique modifications, integrated services (including launch site payload processing, support contractor, range, etc.) and telemetry services. Missions should assume use of commercial spacecraft processing facilities to the maximum extent feasible. Traces from the Guideline to Submit are required, as well as content summarizing New Obligation Authority (NOA) and cost for each mission.

Programmatic Guidance for SMD will be provided at a later date.

Exploration Systems Mission Directorate (ESMD) – Launch Services

The guideline provides funding for Launch Services for the ESMD mission identified by planning launch date and performance range/vehicle class in the enclosed Launch Services above-the-line manifest. LSP is to provide a launch service funding profile for the missions to include basic launch services, estimate for mission-unique modifications, integrated services (including launch site payload processing, support contractor, range, etc.) and telemetry services. Missions should assume use of commercial spacecraft processing facilities to the maximum extent feasible. Traces from the Guideline to Submit are required, as well as content summarizing New Obligation Authority (NOA) and cost for each mission.

Programmatic Guidance for ESMD will be provided at a later date.

Space Operations Mission Directorate (SOMD) – SCaN

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The guideline provides funding for Launch Services for the SCaN missions identified by planning launch date and performance range/vehicle class in the enclosed Launch Services above-the-line manifest. LSP is to provide a launch service funding profile for the missions to include basic launch services, estimate for mission-unique modifications, integrated services (including launch site payload processing, support contractor, range, etc.), and telemetry services. Missions should assume use of commercial spacecraft processing facilities to the maximum extent feasible. Traces from the Guideline to Submit are required, as well as content summarizing New Obligation Authority (NOA) and cost for each mission.

Space Operations Mission Directorate (SOMD) – Launch Services

The guideline provides funding to support the Launch Services across the Agency and to assure requisite sustaining capability (support contractor, facility maintenance, analysis, etc.) necessary to support acquisition and management of the LSP, in support of launch requirements (see enclosed launch services manifests), for NASA and NASA-sponsored missions planned for launch on Expendable Launch Vehicles (ELVs).

Alpha Magnetic Spectrometer (AMS)

GENERAL GUIDANCE:

Proposed changes from this guidance must be supported in detail. Procurement, travel, labor, civil Service FTE, on or near-site WYE and off-site contractor WYE line items are to be addressed. Direct funding adjustments can include zero-sum transfers between budget lines, augmentations, re-pricing, etc.

Johnson Space Center (JSC)/Kennedy Space Center (KSC)

The guidelines to the JSC AMS Project Office (within the JSC Engineering Directorate) and KSC cover the integration of AMS on to the ISS as an externally attached payload, and on to the Space Shuttle launch vehicle.

Rocket Propulsion Test

GENERAL GUIDANCE:

Proposed changes from this guidance must be supported in detail. Procurement, travel, labor, civil Service FTE, on or near-site WYE and off-site contractor WYE line items are to be addressed. Direct funding adjustments can include zero-sum transfers between budget lines, augmentations, re-pricing, etc.

Ground Rules

Resources identified under this line item provide for non program-specific support of propulsion test facilities at Stennis Space Center (SSC), Marshall Space Flight Center (MSFC), Johnson Space Center/White Sands Testing Facility ((JSC/WSTF) and Glenn Research Center/Plum Brook (GRC/PBS). This includes resources for test facility management, maintenance, sustaining engineering, operations, and facility modernization projects required to keep test-related facilities in the RPT approved level of operational readiness. This line does not include resources to support the marginal costs of testing (e.g., direct labor, propellants, materials, program-unique facility modernizations, etc.) which are to be funded by programs as a direct cost.

The following test facilities have been identified by the Rocket Propulsion Test Program (RPT) as "dedicated" to each Center's respective roles/missions with regard to propulsion testing and should therefore be supported by the RPT budget line:

MSFC:	***115, 116, 4670, SPTA, 500***
JSC/WSTF:	***301, 302, 303, 328, 401, 402, 403, 405, 406***
SSC:	***A-1, A-2, A-3, B-1, B-2, E-1, E-2, E-3***
GRC/PB:	**B-2**

Resources should also be included to support other Center facilities such as labs, high pressure gas facilities, test control centers, data handling facilities, propellant transportation, and/or storage facilities that support propulsion testing conducted at the facilities identified above.

A detailed description of the content of each funding category is as follows:

Project Management - The business and administrative processes and services attributable to test facility management, maintenance, and operations which are not associated with specific test programs. This element includes program office management and support. This element also includes the planning, organizing, directing, coordinating, controlling, documenting, and review processes used to accomplish overall program objectives. Examples may include: utilities, transportation, security, networks, custodial, automated data processing (ADP) maintenance, telecommunications, administration (e.g., contractor overhead), etc.

- Systems Engineering - The technical efforts attributable to test facility management, maintenance, and operations sustainment, which are not, associated with specific test programs. This element includes the efforts to define test systems and conduct trade studies; the conduct of design engineering, software engineering, specialty engineering, and system architecture development; the performance of integrated test planning, system requirements writing, configuration control, technical oversight, control and monitoring of the technical program, and risk management activities.

- Safety and Mission Assurance - The efforts of directing and controlling the safety and mission assurance elements of test facility management, maintenance, and operations sustainment, which are, not associated with specific test programs. This element includes design, development, safety assessment, review, and verification of practices and procedures and mission success criteria intended to assure that the test facilities meet performance requirements and function for their intended lifetimes.

Test Technology – The efforts required for the development of technologies and operations approaches that will make testing more efficient, reduce costs, and improve safety. This element includes managing, directing, and controlling of the science investigation aspects and performing the technology demonstration. The costs incurred to cover the Principal Investigator, Project Scientist, science team members, and equivalent personnel for technology demonstrations are included. Specific responsibilities include defining the science or demonstration requirements, ensuring the integration of these requirements with the test facility or article, providing the algorithms for data processing and analyses, and performing data analysis and archiving.

Operations and Sustainment – The requirements for non project-specific operations, equipment, and supplies for all test facilities, test support facilities, control and data facilities, shops, and laboratories. These are primarily labor and material costs required to operate test and test support facilities and to perform activities that directly support testing. This element may include the following items:

High pressure gas	*Weld/carpenter/machine shops*	
High pressure water	*Project control*	*Propellant operations*
Network support	*Chemical Lab*	*Data transmission support*
Environmental Lab	*Environmental support*	*Calibration Lab*

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Info Mgt systems	*Electronic Repair*	*Operations systems*
Valve shop	*Scheduling/planning*	*Electrical/mechanical shops*
Radio operations	*Heavy equipment*	*Logistics support*
SR&QA support	*Test communications*	*Engineering support*

Maintenance – The requirements to maintain test and test support facilities at their approved state of operational readiness, ranging from active to moth balled. This includes all types of maintenance performed on test stands, test support facilities, mechanical and electrical systems, data and control systems, video systems, fire and gas detection systems, and aural warning systems.

Facility Modernization – The requirements for non project-specific capital investments in critical systems to upgrade or replace obsolete, inefficient components and systems. To the extent possible, planned tasks should be itemized by facility, system, and/or test stand.

SPECIFIC GUIDANCE:

The RPT Program maintains a prioritized list of backlogged facility maintenance projects totaling in excess of $150 M. A lull in rocket propulsion test activity has been identified as occurring during fiscal years FY10 through FY12. The program will use this lull to implement as many of those backlogged projects as funding will permit.

As part of the RPT Program Office's efforts to evaluate facility modifications and the workforce skills and levels needed for future Exploration, all Centers are requested to identify critical core capabilities to be supported through the RPT Program for this work. Clearly identify the basis of the estimate, schedule assumptions, workforce requirements (civil service and on-site and off-site contractors), facility requirements, etc. Direct procurement and travel dollar numbers can be found in the 2011 President's Budget. If a different distribution is desired, each RPT Center will respond with the desired split of direct procurement against the following five budget line items: Operations and Sustainment, Maintenance, Facility Modernization, Test Technology, and Project Management.

RPT Decision Packages (DP): NASA has been directed to develop new rocket propulsion engines and technologies to support future Heavy Lift Launch Vehicle (HLLV) operations. This development requires testing of large rocket propulsion engines and systems, upper stages, in-space propulsion systems, and research and development of new propulsion systems. All estimates should cover FY 2011 through FY 2016. Please coordinate with the appropriate program/project offices to provide the following decision packages for potential technology development:

Propulsion Technology Development DP #1: Provide a work plan, with estimates (including WYE and FTE numbers), for the continued development and testing of LH2/LOX rocket propulsion. The work plan should be based on:

- Using an SSME class engine
- Beginning test preparations in FY 2011
- Beginning hot fire testing as soon as facilities and engine hardware are ready.

Propulsion Technology Development DP #2: Provide a work plan, with estimates (including WYE and FTE numbers), for the development and testing of hydrocarbon/LOX rocket propulsion systems. The work plan should be based on:

- Testing a hydrocarbon/LOX fueled engine of a class designed for the first stage of a heavy lift launch vehicle
- Beginning facility preparations in FY 2011
- Include additional costs associated with the performance of stage testing

Propulsion Technology Development DP #3: Provide a work plan, with estimates (including WYE and FTE numbers), for the continued development and testing of LH2/LOX rocket propulsion systems. The work plan should be based on:

- Testing a LH2/LOX fueled engine(s) of a class designed for the second stage of a heavy lift launch vehicle
- Beginning test preparations in FY 2011
- Beginning hot fire testing as soon as facilities and engine hardware are ready.

Propulsion Technology Development DP #4: Provide a work plan, with estimates (including WYE and FTE numbers), for the continued development and testing of CH4/LOX rocket propulsion systems. The work plan should be based on:

- Using an engine with a maximum thrust level of 25K lbf, or testing components necessary for such engine
- Beginning test facility preparations in FY 2011
- Beginning hot fire testing as soon as facilities and engine hardware are ready.

Propulsion Technology Development DP #5: Provide a work plan, with estimates (including WYE and FTE numbers), for the continued development and testing of hypergolic fueled rocket propulsion systems. The work plan should be based on:

- Using a roll and/or reaction control class engine(s)/system(s) that would likely be used in a heavy lift launch vehicle
- Beginning test preparations in FY 2011
- Beginning hot fire testing as soon as facilities and engine hardware are ready.

Propulsion Technology Development DP #6: Provide a work plan, with estimates (including WYE and FTE numbers), for the development and testing of rocket propulsion test technologies. The work plan should be based on:

- Improving the safety or efficiency of liquid fueled rocket propulsion testing
- Addressing existing propulsion test facilities

- Potential propellants and pressurants include: hydrogen, oxygen, methane, hypergols, RP-1, nitrogen, and helium.

Propulsion Technology Development Support DP #7: Provide a work plan, with estimates (including WYE and FTE numbers), for test facility infrastructure maintenance and modifications to support previously defined packages. The work plan should be based on:

- Addressing existing propulsion test infrastructure
- Improving the reliability and efficiencies of systems utilized to support propulsion testing
- Decrease test costs to commercial propulsion customers and NASA propulsion projects

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Human Space Flight Operations

The Human Space Flight Operations (HSFO) budget line includes: Space Flight Crew Operations (SFCO), Crew Health and Safety, and Mission Directorate Support.

General Guidance:

Budget submission is to be reported in **NOA** not cost. The basis for the SOMD 2012 Program Review Guidance (PRG) is the FY 2011 President's budget submission. Proposed changes from this guidance must be supported in detail for each element (procurement, travel, labor, civil service FTE, and total contractor WYE). Additional general guidance is provided under the SOMD general guidance section.

Inclusion of additional projects into HSFO will be studied during the PPBE. The following candidate projects for review include:

- Michoud Assembly Facility (MAF) Operations
- Mission Operations
- EVA
- White Sands Test Facility (WSTF)

Specific SFCO Guidance:

SFCO budget submission to include updates to the agreed upon formats (Amendment #1) see attached:

SFCO PRG
omit templates.p

The SFCO budget submission should include updates to the detailed project financial plan with justifications for each change from the FY 2011 President's budget submission. The level of detail should be consistent with data level provided as back-up to SOMD for the FY 2011 President's budget.

NASA is enlisting the National Research Council to conduct an independent study of the activities funded within NASA's Space Flight Crew Operations program. The study will focus on the following:

- How should the role and size of the human spaceflight office change post Space Shuttle retirement and Space Station assembly?
- What are the crew-related facility requirements after the Space Shuttle program ends?
- Is the astronaut corps' fleet of T-38 supersonic training aircraft and other aircraft a cost-effective means of preparing astronauts for the requirements of NASA's new human spaceflight program?

- Are there more cost-effective means of meeting these training requirements?

Initiation of the study will commence as soon as possible, with goal of being completed in time to inform the FY 2013 budget process.

Specific Crew Health and Safety Guidance:

The guideline provides funding for Crew Health Services, which is to provide the following core services at Johnson Space Center (JSC): Flight Medicine Clinic Operations, Occupational Medicine, Health Services, Human Test Support, Astronaut Strength and Conditioning (ASCR), Radiation Health, Contingency Operations, Clinical Laboratory Operations, Pharmacy Operations, Behavioral Health and Performance. In addition, Crew Health Services is to develop and implement a standardized suite of surveillance plans to track and monitor spaceflight-related health risks for all astronauts. Finally, Crew Health Services is to support the development and interpretation of operational health-related data from space flight by: clinical team (IPTs) support of implementation and evaluation of medical requirements and for rapid response to clinical contingencies; clinical assessments implementation for space medicine issues.

Environmental Monitoring

The guideline provides funding for Environmental Monitoring. Environmental Monitoring is to develop and maintain environment standards for humans during space-based activities; preparation and defense of documents presented to the NRC during committee meetings; survey all available literature on the compounds in question and determination of recommended exposure level based upon National Research Council recommended methods; support of JSC environmental labs.

Medical Informatics & Healthcare Systems

The guideline provides funding for Medical Informatics & Healthcare Systems (MIHCS). MIHCS is to archive astronaut medical record information in database form and perform data analyses to support clinical care, and long-term health assessments of the astronaut corps using evidence-based medicine methodology. MIHCS is to design, implement, and maintain a comprehensive data management infrastructure to support the objectives of Crew Health and Safety. MIHCS is to maintain an electronic medical record for real-time documentation of clinical care at the point of care. MIHCS is responsible for evaluating and continually enhancing the clinical care systems available on-orbit. In addition, various clinical technologies are evaluated for their potential to enhance the standard of care during missions. MIHCS supports the definition and implementation of medical care system requirements for all mission types in conjunction with medical operations efforts.

NASA Human Health and Performance Center

The guideline provides funding for the NASA Human Health and Performance Center (NHHPC) based at the Johnson Space Center. It is to utilize stakeholder participation to prioritize and focus partner efforts by integrating all activities and disciplines of the human system. It is to maximize the use of resources by avoiding duplication of efforts in the human system across the agency, and focus on the highest human health and performance risks and needs. The NHHPC facilitates knowledge management, development and implementation of innovative approaches, and communication of needs and outcomes. It should promote the use of collaboration/open innovation to solve human system portfolio needs. It establishes an entity at HQ SOMD and administered by JSC to integrate activities through a multi-organizational executive council. The NHHPC should draw upon expertise to inspire our youth through STEM education and to create enduring support for space exploration from the general public.

CHS Decision Package #1: Provide an update to what would be required to provide the proposed comprehensive medical care to astronauts, former astronauts, retired astronauts and dependents. Specific information that is needed for this decision package includes:

- A complete description of the health care program that is anticipated.
- Rationale for such a program to include benefits to NASA.
- A description of the annual costs to NASA for such a program, for FY 2012-FY2016.
- An estimate of the personnel requirements needed to administer such a program to include civil servants and contractors, for FY 2012 – FY 2016.

Appendix F. GRC Issue Paper – White Sands Test Facility (WSTF Decision Package) – SOMD PRG, date June 4, 2010

GRC Issue Paper **6/4/10**

Subject: White Sands Test Facility (WSTF Decision Package) – SOMD PRG

Program/Center: SOMD/RPT/Glenn Research Center (GRC)

Issue:
GRC strongly disagrees with the recommendation made by the Rocket Propulsion Test (RPT) Program in the SOMD PPBE 12 Program and Resource Guidance (PRG) submission to close and demolish the GRC Altitude Combustion Stand (ACS) and Rocket Component Laboratory (RCL) 32 as necessary actions to help preserve the minimum infrastructure and skill sets needed for future operations at WSTF.

Background:
(PRG Statement dated May 7, 2010) White Sand Test Facility (WSTF) Decision Package Items 3 and 4

3. Close the GRC Altitude Combustion Stand (ACS) and transfer all functions, testing, and related funding to WSTF.
   a. GRC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Thermal Vac Propulsion testing at Altitude Combustion Stand (ACS)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	Notes
GRC Capability O&M	$ -	$ -	$ 184	$ 189	$ 195	$ 201	$ 768	*Updated 2/9/2010 - GRC O&M estimate w/ inflation*

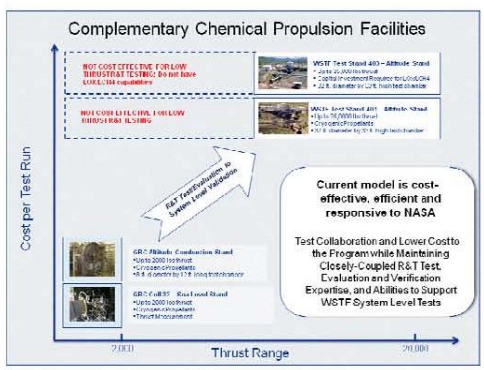
   b. SOMD / ESMD provide $800k to dismantle and relocate Propellant Conditioning Skid and other items for spares from GRC ACS and RCS 32 to WSTF
   c. GRC to seek Agency Strategic Institutional Investment funds to demolish ACS.

4. Close the GRC RCL Test Stand 32 and transfer all functions, testing, and related funding to WSTF.
   a. GRC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Propulsion Testing at RCL Test Stand 32 (ambient testing)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	Notes
GRC Capability O&M	$ -	$ 134	$ 142	$ 146	$ 151	$ 155	$ 729	*Updated 2/9/2010 - GRC O&M estimate w/ inflation*

   b. GRC to seek Agency Strategic Institutional Investment funds to demolish RCL-32.

Discussion:
The subject PRG recommendation does not recognize the value and proven successes of the current working model that is cost-effective, efficient and responsive to NASA missions. In the current model, R&T and single engine testing for engines rated at 100 to 2000 lbf are conducted at GRC's ACS and RCL32, and large engine (between 2000 and 25,000 lbf) and system level validation are conducted at WSTF. This working model results in test collaboration and lower cost to the Program while maintaining closely-coupled R&T test, evaluation and verification expertise at GRC, and abilities to support WSTF system level tests.



The subject PRG recommendation does not recognize the new ESMD and Space Technology formulation efforts that will require increased use of ACS and RCL32 for LOX/RP, LOX/methane and/or LOX/hydrogen propulsion test at the component and single engine levels to enable heavy lift propulsion option evaluation. The recommendation to close ACS and RCL32 will provide a void in the Agency's space propulsion test portfolio.

The subject PRG recommendation does not incorporate the net results of higher cost, negative schedule impact and technical risks to programs in transferring R&T test capabilities to WSTF. The following factors were not recognized:

- Propulsion research and technology is a core competency at GRC. A significant propulsion development capability is resident at GRC and University and industry partners in the region.
- R&T testing requires quick turnaround, robust experimental measurements, and high throughput capabilities that are not inherent in the WSTF facilities.
- Programs sponsors will be expected to absorb higher operating and facility build costs, and delays in testing. WSTF may be expected to share the costs associated with facility buildup.
- Successful tests require close collaboration between R&T and facility test engineers and technicians; R&T personnel on-site test support will be in-efficient and require significant increase in travel.

The subject PRG recommendation does not recognize the risk associated with transferring the ACS Propellant Conditioning Skids to WSTF. GRC ACS propellant conditioning skids are not compatible with WSTF facilities. Pressure drop and heat leak are too high in WSTF facilities, and ACS's system is not compatible with WSTF's vacuum environment.

The subject PRG recommendation does not recognize the impact to GRC. It does not consider workforce and competency impact, including reassignment of 4 Civil Service Personnel, and laying off 5 on-site contractors in the space propulsion R&T test competency due to loss of test activities. Additionally, it does not recognize the impacts on external partner alliances fostered by NASA chemical propulsion R&T competencies and capabilities. Specifically, by recommending demolishing of the test facilities, it does not recognize the recent investments in capabilities that are unique to R&T and costly to duplicate elsewhere.

- ACS (a recent $20M airport relocation investment) and RCL32 (state-of-the-art laser diagnostic capabilities) are an integral part of GRC chemical propulsion test, evaluation and verification competency and an integral part of a suite of integrated propulsion laboratories.

The subject PRG recommendation does not recognize the approved GRC Facilities Master Plan that does not include in its scope the demolition of ACS and RCL32 for reasons provided above. The subject PRG recommendation does not recognize the Agency Strategic Institutional Investment intent and process that support the implementation and execution of Centers' master plans. The subject PRG recommendation does not recognize the on-going Agency IRP team activities to resolve and solve institutional capabilities from an Agency integrated perspective.

Alternatives:
Alternative 1 – Status Quo, Maintain ACS and RCL32 capabilities

- Pros:

  - Providing strategic, cost effective, integrated test capabilities to support NASA missions using ACS and RCL32 for component and single engine testing (between 100 and 2000 lbf) and WSTF for large engine and system level verification (between 2000 and 25,000 lbf)
  - Providing critical support to the new ESMD and Space Technology programs for LOX/RP, LOX/Methane and LOX/Hydrogen component and single engine testing to evaluate heavy lift propulsion options
  - Maintaining NASA chemical propulsion R&T competency to perform component and single engine test and evaluation, and support WSTF system level verification
- Cons: None -- WSTF test capability is part of the integrated solution.

Alternative 2 – PRG recommendation

- Pros: None. No quantifiable net benefit to WSTF
- Cons:
  - Significant negative impact to new programs, to Agency space propulsion R&T, and to external partners.
  - Higher schedule, cost and technical risks associated with conducting component and lower thrust engine testing at WSTF, e.g. higher test cost at WSTF, lower test throughput, lack of advanced instrumentation.
  - Higher build cost, including build up of new propellant skids at WSTF. (GRC ACS propellant skids are not compatible with WSTF facilities)
  - Travel requirement for GRC R&T personnel on-site support at WSTF – inefficient
  - Cost to demolish state-of-the-art chemical propulsion R&T facilities at the expense of R&T – Inconsistent with the approved GRC Facilities Master Plan

Cost Summary ($K and FTE): If implemented, the subject PRG will have the following impacts:

- GRC Test Service Pool impact (~$350K per year) as stated in the PRG above.
- GRC Workforce impact due to loss of R&T test activities: 4 FTEs and 5 WYEs
- Build up of new propellant skids at WSTF: $1M to $2.5M
- Test Cost: 2X and higher at WSTF
- R&T support cost at WSTF: $3K per person per week for travel
- ACS and RCL32 demolition: ROM $3M to $5M

Estimated Cost Impact to Agency:

Transferring R&T Testing to WSTF TS401 will incur capital investment, higher build up costs, higher operating costs and personnel travel costs. Below is an estimated comparison between TS401, ACS and RCL32, based on FY10 PCAD project LOX/Methane 100 lbf testing.

	Thrust, lbf	Test Run per Day	Capital Upgrade	Pre-Test Build Up	Average Monthly Test Cost Based on PCAD actuals	R&T Personnel On-Site Suppport (5 months per year based on FY10 Test Plan)	Sustainment Cost
WSTF TS401	up to 25,000, Altitude Test	4	- Heat Exchanger Unproven to meet PCAD temperature limits - Propellant conditioning system not included; PCAD estimate ($2.4M) vs WSTF previous estimate ($750K)	WSTF estimate $715K (including reserve) PCAD experience: $2500K	$350K	$130K/year (2 people, $3K/person/week travel, 5 months)	~$1.2M/year
GRC ACS	up to 2,000, Altitude Test	10-12	none	none	$146K	none	~$180K/year
GRC RCL32	up to 2,000, Sea Level Test	>12	none	none	$125K	none	~$140K/year

Recommendation: Alternative 1 with concurrence at the Mission Support Council.

Appendix G. White Sands Test Facility Capability Review, TCB-07-03072007, Dated August 28, 2007

White Sands Test Facility Capability Review

TCB-07-03072007

August 28, 2007

White Sands Test Facility
Capability Review

Executive Summary

The Transition Control Board issued TCB Action TCB-07-03072007 requesting a third party independent assessment of White Sands Test Facility (WSTF) capabilities. The purpose of the study was to identify information that would support NASA in making decisions effecting the FY 09 PPBES budget cycle and budget run out. Identify consolidation opportunities when they exist. To complete this review, the study team reviewed recent studies and other information relating to the White Sands Test Facility.

Summary of Findings and Recommendations

Finding 1: WSTF is required to support human space flight activities at least through the end of the ISSP. Current budget projections indicate a significant budget shortfall following Space Shuttle retirement.

Recommendation 1: WSTF should pursue increasing the amount of reimbursable non-NASA metrology work.

Recommendation 2: NASA should maintain materials and chemical analysis capability at WSTF for the near term.

Recommendation 3: NASA should retain the High Energy X-Ray Facility at WSTF to support material analysis.

Recommendation 4: NASA should mothball the Liquid Hydrogen Recirculating Pump Test Facility beginning in 2011, possibly disposing of the facility as early as 2011 if no new work is identified.

Recommendation 5: NASA should begin disposal of the WSTF Low Velocity Impact Test Facility as soon as possible.

Recommendation 6: NASA should consolidate micrometeoroid hypervelocity impact testing at WSTF.

Recommendation 7: NASA should retain the High Energy Blast Facility but investigate DoD capabilities in this area to determine if NASA could utilize a DoD test facility to meet NASA's requirements.

Recommendation 8: NASA should retain the Composite Over-wrapped Pressure Vessel Safety Assessment Test Area at least through the end of the International Space Station Program. Constellation program should investigate using this facility.

Recommendation 9: Constellation Propulsion Test Integration Group (PTIG) should conduct trade studies to determine the best solution for testing of Orion Service Module and Command Module Reaction Control Engines in support of a strategic decision regarding maintaining or eliminating/ downmoding test capability in the 300 and 400 Propulsion Test Areas. If the Agency makes a strategic decision to retain testing capability at the 300 and 400 areas currently under RPT Program stewardship, NASA should consider consolidating small-scale component and subsystem testing at WSTF to reduce the expense of maintaining component and subsystem test stands at other sites.

Recommendation 10: NASA should divest of White Sands Space Harbor beginning in 2011. NASA should direct Johnson Space Center to begin negotiations with WSMR no later than 2008.

Recommendation 11: NASA should retain the capability to test hypergolic propellant engines and propulsion systems independent of the vendors.

White Sands Test Facility
Capability Review

Introduction

White Sands Test Facility (WSTF) occupies 28 square miles in the southwest corner of the Army's White Sands Missile Range, near Las Cruces, NM. The facility employs 56 NASA employees and 631 contract employees. The test facility's annual budget is approximately $60 million.

The facility was originally constructed in the early 1960's to support the Apollo program. Since that time WSTF has conducted more than 3.5 million test firings and provided testing of integrated propulsion systems for Apollo, Skylab, Pioneer, Viking, Cassini, and Space Shuttle. The facility provides specialized expertise in the areas of simulated altitude testing of full scale integrated hypergolic propulsion systems; repair of hypergolic, hydrogen and oxygen propulsion system components; materials testing for man rated space flight systems; design and hazards analysis of hydrogen and oxygen systems; large scale explosion testing; and component testing in high temperature - high flow gaseous oxygen and hydrogen. The site also includes the White Sands Space Harbor (WSSH) which is used for approach training for Shuttle astronauts and is an alternate landing site for the Space Shuttle.

WSTF offers a large buffer zone and holds existing hazardous materials environmental permits. This makes the site ideal for testing of hypergolic propulsion systems.

White Sands Test Facility provided two separate briefings to the Transition Control Board (TCB). The first briefing was an informational overview of the White Sands Test Facility, presented to the (TCB) in October 2006. The second briefing was in response to a specific TCB tasking to conduct a self evaluation of WSTF capabilities and transition impacts. This evaluation was completed and presented to the TCB in March 2007. As a result of the March presentation, the TCB issued TCB Action TCB-07-03072007, requesting further study of WSTF to provide transition related recommendations. The Terms of Reference for this study were drafted in May 2007, initiating this study.

Purpose

Conduct a review of the White sands Test Facility (WSTF) capability assessment to identify information that would support NASA in making decisions effecting the FY 09 PPBES budget cycle and budget run out. Identify consolidation opportunities when they exist.

Study Approach

The study team evaluated information provided by White Sands Test Facility (WSTF), to the Transition Control Board (TCB) in October 2006 and in response to the TCB action TCB-02-102706. The team supplemented the WSTF information with other studies recently conducted. The Johnson Space Center (JSC) Transition Facilities Review provided Space Shuttle Program (SSP) last need dates for many WSTF facilities and identified potential work at WSTF through the end of the International Space Station Program (ISSP).

The Study Team utilized available reports, the NASA Major Facilities Inventory, and information provided by WSTF to identify the capabilities supported by each of WSTF's major facilities.

Using the JSC Transition Facilities Review, the WSTF Study Team identified functional areas within 46 facilities that do not have specific work identified between 2007 and 2012. These functional areas represent potential near term underutilized capacity at WSTF. The study team focused the review on these functional areas to provide findings and recommendations that will impact NASA near term budgets.

To determine the potential need for the potential underutilized functional areas, Study Team members from Constellation program, Exploration Systems Mission Directorate, and Space Operations Mission Directorate presented the listing of these functional areas facilities to Constellation Test Integration Groups (TIGs), and the Rocket Propulsion Test Program (RPTP). Some team members conducted a site visit to WSTF as part of an ESMD & Constellation data collection visit. In a few cases, the TIGs and RPTP were able to identify facilities that have no known requirement in the foreseeable future. In some cases, facilities on the list may be needed to meet a Constellation or rocket propulsion test requirement or for risk reduction but Constellation had insufficient information to be able to identify the facility as a definite requirement.

The scope of the study was focused on findings and recommendations that would support near term budget decision making. Periodic follow on studies may be required as Constellation requirements, designs and processes mature.

Study team members are identified in the table below:

Name	Organization
Jim Wright	Facilities Engineering and Real Property, NASA Headquarters
Scott Robinson	Facilities Engineering and Real Property, NASA Headquarters
Dwight Auzenne	Johnson Space Center, Office of Analysis and Assessment
Ron Bailey	Johnson Space Center, Planning and Integration Office
Frank Bellinger	Exploration Systems Mission Directorate, Infrastructure Manager
Perri Fox	Johnson Space Center, Planning and Integration Office
George Madzsar	Strategic Capabilities Asset Program
Jon Haas	White Sands Test Facility
Harry Johnson	White Sands Test Facility
Patrick Kelly	Space Operations Mission Directorate

Name	Organization
Tina Norwood	Environmental Management Division
Heather Pizzamiglio	Space Operations Mission Directorate
Mike Showers	Logistics Division, NASA Headquarters
Roy Young	Constellation Program, Test and Verification Office

References:

a. Terms of Reference, White Sands Test Facility Capability Review, dtd May 30, 2007
b. SEITT, December 2006
c. JSC Transition Facilities Review, dtd March 2007
d. "Rocket Propulsion Test Capability Alignment Study," The Aerospace Corp., Report ATR-2007(5175)-2, June 21, 2007.
e. WSTF Test Facility Overview, Shuttle Overview, October 2006
f. SOMD FY 09 draft PPBES Budget Overview
g. HSF Core Capability Assessment
h. Human Space Flight Capabilities Forum
i. Major Facilities Inventory (web page maintained by NASA Facilities Engineering and Real Property Division).

Discussion

WSTF provides expertise and facility infrastructure capability primarily in rocket propulsion testing and hazardous fluids-materials testing. Rocket propulsion testing includes testing of hypergolic and non-toxic (primarily LOX/Methane or Ethanol) propulsion systems at simulated altitude up to 25,000 lbf and ambient up to 60,000 lbf. Hazardous fluids-materials testing includes hypergolic propellant handling; oxygen systems; materials characterization and qualification; International Space Station hardware repair; oxygen compatibility; and testing and anomaly resolution of composite pressure vessels. Some of these areas of expertise are unique to WSTF and are vital to the support of the International Space Station even after the Space Shuttle has been retired. Therefore, it will be necessary to maintain some core functions at WSTF throughout the life of the International Space Station program. Many of these core functions have already been identified as part of the JSC Transition Facilities Review.

Budget Support for WSTF: The estimated budget run out for SOMD support of WSTF indicates that SOMD funding for WSTF will be reduced from $19.6 million in FY 2008 to $5.1 million in FY 2011. This 74% reduction in SOMD funding will result in a substantial increase in cost for the remaining services at WSTF unless additional work can be identified to offset overhead expenses and/or reductions can be made in overhead costs and unused infrastructure. Current ESMD budget projections do not identify baseline funding for WSTF. Constellation program has identified some work to be completed at WSTF, but an ESMD estimated budget run out for WSTF could not be obtained for this study.

Environmental Liability: Apollo test operations resulted in N-nitrosdimethylamine (NDMN) and Dimethlamine (DMN) contamination of the groundwater at WSTF. Cleaning activities during site construction and Apollo test operations also resulted in Freon TF, Freon MF, and trichloroethylene contamination of the groundwater. Groundwater contamination was discovered in 1985. The plume is four miles long, 1.5 miles wide and approximately 300 feet thick. WSTF currently operates extraction wells, a remediation system, and injection wells to remediate the ground water contamination. The remediation is closely monitored to ensure contamination does not reach drinking water sources in the area. WSTF also manages numerous solid and hazardous waste management units. There is no contamination at the WSSH site.

Projected clean-up cost is $300 million and will take 55-60 years. This is an annual cost of $5 million - $6 million per year in current dollars. Remediation is accomplished by permanent onsite contractors who monitor the remediation system. It is possible to transfer title of brown field (contaminated) property by adding environmental liability clauses to the land transfer or lease agreement. The lease/ title transfer agreement would identify the long-term responsible party for clean-up. Maintaining the WSTF clean up within the NASA budget would allow NASA to retain control over the environmental liability, control clean up costs and involve NASA in land use decisions to prevent decisions that would be contrary to clean up efforts.

Contamination at WSTF is only associated with historic operations. Current operations at WSTF are properly permitted and monitored. Current operations meet Federal and State of New Mexico hazardous waste regulations. Current WSTF operations are not contributing to existing site contamination. No additional contamination is anticipated in the future.

As a result of a review of material provided by WSTF and the JSC Transition Facilities Review, the Study Team identified functional areas in 46 facilities at WSTF that either have no work now, or may be at risk of having insufficient work at some point prior to 2012. These functional areas are discussed below.

Metrology: WSTF maintains a calibration laboratory in support of its testing work. WSMR also requires metrology services to support testing on the range. WSTF currently provides calibration services to Air Force and Army clients in an effort to reduce the overall costs to NASA testing operations. WSTF should pursue additional non-NASA clients for these services. WSTF could even pursue a consolidated contract with WSMR for these services in the future.

Materials and Chemical Analysis: WSTF performs testing and analysis of materials to better understand, improve, and verify the systems, capabilities, and materials used in space flight, and ensure safety during manned space flights. These analytical laboratories have work projected through 2016. The Constellation Environmental Test and Integration Group has identified a need for specific capabilities. The results of this analysis are included as Appendix B in this report. Similar work is done in laboratories at MSFC. Both the MSFC and WSTF laboratories have sufficient work to justify maintaining both sites for the near term. Maintaining both sites provides surge capacity to support critical workloads such as forensic engineering following a major incident. Some efficiency and overhead reduction might be possible by consolidating the WSTF and MSFC labs at one site at some point in the future. Consolidating the labs would require a detailed review of capabilities and workload at each site. Consolidating the labs would also require a change to NASA Standard 6001, which utilizes round robin testing at separate sites to ensure process consistency. Eliminating this analytical capability at either site would negatively impact sustaining engineering at that site.

High Energy X-Ray Facility: This facility is an individual lab within building 203. The facility is utilized approximately 20% of the time but is a valuable tool in evaluating material anomalies. The facility is currently providing support for the CEV shield. The facility is expected to provide support if WSTF is tasked with additional material test work for Constellation. A redundant facility was not identified in the Major Facility Inventory. X-Ray evaluation facilities are key evaluation tools when doing materials evaluation work and would be expected at most sites where materials evaluation takes place. The high-energy X-Ray facility should remain at WSTF as long as WSTF continues to conduct materials evaluation work.

Liquid Hydrogen Recirculating Pump Test Facility: This facility is part of the High Flow Gaseous Oxygen, Hydrogen, and Nitrogen Test Facility. The facility is configured to provide support that is specific to Space Shuttle Program (SSP). SSP is planning to remove the components that are unique to Shuttle. The facility may support testing for other programs once the SSP unique components are removed. SSP has no requirement for the facility after 2010 but has committed to funding the facility through 2010. No new definite work has been identified for this facility.

Marshall Space Flight Center (MSFC) has a Hydrogen Cold Flow Test Facility that can provide test capability that is similar to the WSTF facility. The MSFC facility currently has no work projected, but MSFC has proposed the facility for use by CLV. It is unlikely that there will be sufficient work to support both hydrogen cold flow facilities. By retaining the MSFC facility, NASA would still retain hydrogen cold flow testing capability if the WSTF Liquid Hydrogen Recirculating Pump Facility is closed. The facility currently employs 0.2 FTE's and 1.6 WYE's in its operation.

Low Velocity Impact Test Facility: This facility is capable of launching benign projectiles at relatively non-toxic or non-hazardous targets. The facility has not been in use since 2006 and there is no planned work for the future. The facility offers no unique capability and could be easily transferred to another NASA site. There are other NASA sites such as Glen Research Center and Ames Research Center that have impact testing capability. Transferring this capability to one of those sites could result in a reduction in future low impact testing costs.

Hyper-velocity Impact Testing: The White Sands Test Facility (WSTF) hyper-velocity guns provide a unique capability to the Micro-Meteoroid and Orbital Debris (MMOD) community. The WSTF hyper-velocity test facility provides the only testing capability for real-time anomaly resolution. This capability is required to mitigate a top program risk for the ISSP. The ISSP need is currently projected through 2010 but ISSP support may not extend beyond that time period. The capability will also be required by Constellation to mitigate micro-meteoroid and orbital debris risk for Orion and Lunar Surface Access Module (LSAM).

Although micrometeoroid hyper-velocity impact testing is a critical capability, there is insufficient work to support more than one test site in the Agency. NASA eliminated redundant capability in this area in the past by consolidating micrometeoroid hyper-velocity impact testing at WSTF. Because of WSTF's capability to handle hazardous materials, WSTF is the only facility capable of impact testing hazardous targets. Consolidating micrometeoroid hyper-velocity impact testing at WSTF allowed NASA to eliminate redundant capability, reduce operating costs, and maintain test workforce proficiency.

In recent years, other NASA sites have pursued acquiring hyper-velocity impact test capability. A recent Constellation Environmental Test Integration Group review indicated that MSFC is currently re-building super-sonic particle impact testing capability. Projected work in this area is insufficient to support multiple testing sites. The result is capacity beyond NASA's need. NASA should renew its effort to consolidate micrometeoroid hyper-velocity testing at WSTF.

WSTF capability to perform micrometeoroid testing is not redundant with Ames capability in aeroballistic testing and planetary impact testing. WSTF does not have the capability to perform this type of testing. Consolidating this type of testing at WSTF is not recommended unless a specific cost analysis demonstrates a long term cost savings. The Constellation Environmental Test Integration Group (ETIG) conducted a review of NASA impact testing capability. A summary of the ETIG review is provided as Appendix D.

<u>High Energy Blast Facility</u>: This facility can test explosive charges up to an equivalent blast of 500 lb TNT. The facility is currently mothballed but is used periodically. The cost to maintain the capability in mothball status is low, approximately $10,000 - $20,000 per year. Reusing the facility would require a cost to reactivate. Reactivation would include inspection and repair of wiring and re-calibration of sensors and instruments. There is no other NASA facility with this capability, but the capability may exist at a DoD test facility. Although the facility should be maintained in mothball status in the near term, NASA should investigate whether a similar capability exists at a DoD site. NASA should market the capability to increase the utilization and generate reimbursable work. If the capability exists at a DoD site, NASA should investigate demolishing the facility and meeting occasional NASA test requirements by using a DoD facility.

<u>Composite Over-wrapped Pressure Vessel Safety Assessment Test Area</u>: This facility is capable of testing pressure vessels in hydraulic test mode with pressures up to 30,000 psi, at defined pressurization rates including testing to burst. The facility is also capable of long duration testing of pressure vessels at elevated pressures in either an impact-

damaged or manufactured-defect condition. Although there is no committed work beyond 2012, this facility continues to receive steady work. There is an interest on the part of ISS and probably Constellation to evaluate long term life capabilities of composite over-wrapped pressure vessels. WSTF has already completed some preliminary testing of composite over-wrapped pressure vessels for Constellation. These pressure vessels offer a great weight advantage that makes them strong candidates for Constellation designs. Constellation has identified testing requirements for FY08 but has not identified a long term test schedule. This facility is seen as a critical test facility for evaluating composite pressure vessels. There is no other facility at any other NASA site with this capability. This facility should remain at WSTF at least until the end of the ISS program.

Rocket Propulsion Test Area 300 & 400: According to the RPT program test stand database and WSTF management, the facilities identified in the 300 & 400 test areas include Test Stand 301, Test Stand 302, Test Stand 303, Test Stand 328, 300 Area Small Altitude Simulation System, The Hypergolic Propellant Storage, Conditioning, and Distribution System, Inert Gas Storage and Distribution systems, Fire Detection and Suppression systems, Instrumentation and Control Systems, support buildings and associated test support systems. Test Area 400 includes Test Stand 401, Test Stand 402, Test Stand 403, Test Stand 405, and Test Stand 406. Appendix D provides RPT information of current utilization commitments. The 400 area includes the Large Altitude Simulation System to support engine tests up to 25,000 lbf and the Small Altitude Simulation System to support engine tests up to 1,000 lbf. Also included are Hypergolic Propellant Storage, Conditioning and Distribution System, Liquid and Gaseous Oxygen, Hydrocarbon, and Liquid Methane propellant storage and supply systems, Inert Gas Storage and Distribution systems, Fire Detection and Suppression systems, Instrumentation and control Systems, support buildings, and associated test support systems.

These test areas provide testing capability for component, subsystem and thrusters at ambient (i.e. atmospheric) and at simulated high-altitude pressure conditions. Thrust capability ranges up to 25,000 lbf at simulated altitude to 60,000 lbf at ambient pressure conditions. These test complexes are hypergolic propellant capable but can also test using LOX and hydrocarbon propellants (including methane). The only definite test projects/ series identified for these test complexes beyond 2010 are at Test Stand 328 which will perform Peacekeeper demilitarization for the Air Force until FY 2012 and at Test Stand 401 which will perform Minuteman testing for the Air Force through FY 2014. The 300 & 400 Test Areas are the Agency's only facilities that can test hardware that utilizes hypergolic propellants. Mothballing or closing these facilities would limit the Agency's ability to perform NASA in-house hypergolic testing.

Current Orion designs include use of hypergolic propellants. With Orion plans to use hypergolic fuels, the Agency will have a requirement for testing engines using hypergolic fuels throughout the Orion project. This capability should be retained at WSTF but not expanded to other locations. Expanding the capability to test engines using hypergolic fuels to other locations will increase NASA's costs to establish and maintain the necessary environmental permits and controls at new sites; and expose the Agency to a risk of a hazardous spill at those sites.

NASA has 2 other test complexes that can conduct testing on propulsion components and subsystems, although of larger scale and with different propellants (e.g. Hydrogen, Kerosene, Hydrogen Peroxide, etc.). These complexes are the E-Complex at Stennis Space Center (stands E-1, E-2, E-3) capable of up to 750,000 lbf at ambient pressure, and test stands 115 and 116 at MSFC. In addition, there may be some small-scale component level test capability evolving at Glenn Research Center. However, the WSTF test facilities are the only facilities with the capability to test with hypergolic propellants and that can test to simulated altitude pressures. It is also possible to conduct ambient pressure component and subsystem tests and tests with selected non-hypergolic fuels at the WSTF 300 & 400 areas (ethanol and methane), providing some redundant testing capability to the MSFC and SSC test complexes.

In the long term, very little work is anticipated for the E-Complex at SSC. Consequently, the E-Complex at SSC could be downmoded or mothballed through the RPT Program board process. If new component or subsystem testing requirements are identified in the future, the WSTF test facilities could be examined to see whether they might meet new test requirements (scale and propellants being important facility capability criteria). Test stand 115 and 116 at MSFC are subject to similar considerations. If no work is identified for the MSFC facilities by 2010, NASA could consider downmoding the MSFC component test stands with a potential for consolidating small scale (less than 60 klbf thrust scale) component and subsystem testing at WSTF.

The annual “ready to produce” cost for the 300 and 400 areas combined is $10.2M. Maintaining the complex requires 8 FTE and 68 WYE. “Ready to produce” includes maintenance and operation of the test capability to produce products (testing and test data for NASA programs) in the normal configuration of the test stand or test capability. Any modification of the test stands to meet test unique requirements is not included in the “ready to produce” cost estimate.

The Rocket Propulsion Test Program is considering and advocating use of the 300 and 400 test areas for testing of the Orion Main engine, Service Module Reaction Control Engine acceptance testing, Command Module Reaction Control Engine acceptance testing and simulated altitude tests. This work has not been assigned to WSTF yet, awaiting development of Orion planning. The RPT Program has assigned CLV first stage roll control and upper stage Reaction Control systems testing to WSTF.

The Constellation Propulsion Test and Integration Group (PTIG) has identified the 300 and 400 test areas as potential sites to provide testing for the Service Module and Command Module Reaction Control Engine development, or has identified the site as part of a risk mitigation strategy for this development. In addition to the Orion work, the Propulsion Test Integration Group has identified the test areas as potential sites for Lunar Lander engine testing, and Ares 1 first stage roll control and upper stage Reaction Control System testing.

The Orion project has selected Aerojet for engine development of the Service Module and Command Module Reaction Control Engines. Aerojet has proposed using Aerojet facilities for the engine testing. This involves both Sacramento (CA) and Redmond (WA) test capability belonging to Aerojet. Aerojet test facilities presently do not have the capability to test complete system level and nozzle extension tests at their facilities. Aerojet does not have a facility that can perform hot fire qualification test article (HFQTA) testing for the service module. NASA believes that Aerojet (in Sacramento) will have to construct a new test stand, or modify one of their existing test stands, in order to meet these requirements. This belief is based upon informal conversations during technical interchanges in Spring 2007.

In addition, the Aerojet-Redmond test facilities are located in an industrial park in the Redmond metropolitan area. Long term, there is a risk that activities that are incompatible with rocket engine testing could encroach on the Aerojet-Redmond test sites. Aerojet-Sacramento hypergolic facilities are remotely located, but their LOX/LCH4 facilities are within sight of a high school and a large industrial area, and will likely need to be relocated to a remote test area. WSTF's risk of urban encroachment on their rocket propulsion test facilities is much lower than the risk at Aerojet because of WSTF's buffer zone and remote location. As a result, the 300 and 400 test areas at WSTF may be more viable long term than the Aerojet test facilities.

Where NASA decides to assign this Constellation test work will impact the cost of the remaining work at WSTF and the overall cost to NASA to conduct component and subsystem propulsion testing at the smaller scale (i.e. less than 60klbf). The decision will also impact NASA's ability to retain the WSTF test capability long term so that it is available for testing later Constellation systems. The decision may also affect NASA's ability to maintain sustaining engineering capability for these propulsion systems and the core competency in the rocket propulsion testing area.

The Rocket Propulsion Test Program provided the estimated Facility Utilization Schedule for White Sands Test Facility. This schedule is included as Appendix E.

<u>500 Area</u>: The 500 area includes inert gas storage, cryogenic storage, and breathing air compressor and storage. These facilities support all of the propulsion test areas at WSTF and provide inert gas and breathing air to the laboratories as well. These facilities will be required as long as WSTF continues to provide hazardous test services.

<u>White Sands Space Harbor</u>: The White Sands Space Harbor includes the control tower, operations control center, communications center, de-servicing pad, dispensary trailer, and maintenance buildings. The site also includes 3 lakebed runways. There is no NASA requirement for the facilities at the White Sands Space Harbor after the last Shuttle flight. The Constellation program has not identified a need for Space Harbor.

White Sands Space Harbor (WSSH) is owned by the Army's White Sands Missile Range (WSMR) and utilized by NASA for Space Shuttle Program training and mission support. NASA does not have exclusive use of the site, but operates under the terms of an

Interservice Agreement between the Department of the Army and NASA. The most recent agreement was signed by the Director of the Johnson Space Center (JSC) and the Commander of WSMR in 1990.

NASA is responsible for maintenance of NASA owned facilities at WSSH. The NASA WSTF contractor performs WSSH maintenance, operation, repair, construction, and modifications under the WSMR regulations.

NASA will retain property accountability for all buildings and structures at WSSH which have been constructed with NASA funds, until the Manager (NASA-WSTF) notifies WSMR that NASA is ending the use of the buildings. Upon termination, the site must be restored to its former condition by NASA, if required by WSMR. NASA may, with WSMR concurrence, abandon improvements in place and transfer such improvements to WSMR in satisfaction of the NASA obligation to restore the site.

Upon termination of building use, NASA may remove the equipment purchased with NASA funds, as it desires. NASA may be required to restore structural damage to buildings becoming the property of WSMR if equipment removal damages building structures. Restoration costs are NASA's responsibility.

Termination terms are negotiable and will determine the scope of the demolition required. If WSMR allows NASA to abandon airstrips in place, the cost to return the airstrip to natural desert condition can be eliminated. WSMR may also request that some of the buildings at the site remain, eliminating those demolition costs. ESMD is exploring the possibility of finding another user to assume management of the site after shuttle retirement. The new tenant would work directly with WSMR to negotiate a new lease for the future. This approach would reduce overall demolition costs to NASA

WSTF estimates the worst case cost to divest from WSSH as $16.4 million over 3 years. These costs also include suspension of operations at El Paso Airport and suspension of fire crash rescue support from Holloman AFB. It is believed that this number can be reduced based on negotiations of the termination terms with WSMR. Termination of WSSH will affect 1 FTE and 24 WYE's. Terminating operations at WSSH will save an estimated $4.6 million in annual operating costs. The estimated replacement value of the WSSH facilities is $2.9 million. This replacement value does not include the airfields. The airfields are owned by WSMR, not NASA, so they are not included in NASA's real property inventory. The estimated cost to bring the facilities to excellent condition is $54,000.

WSTF should begin termination negotiations with WSMR in 2008. Planning for demolition of facilities and divestment from the site can also begin in 2008. Divestment will require establishing termination terms for the Inter-service agreement with WSMR and design of demolition of the facilities.

Findings and Recommendations

Finding 1: The White Sands Test Facility is required to support human space flight activities at least through the end of the ISSP. NASA's Space Operations Mission Directorate projected budget supporting WSTF indicates a reduction of support after 2010 by approximately 74%. This reduction in support will result in a significant budget shortfall at WSTF. Elimination of this budget shortfall requires bringing new work to WSTF, a substantial reduction in the WSTF infrastructure, an increase in cost for the remaining services provided by WSTF or a combination of the three.

Recommendation 1: WSTF should pursue increasing the amount of reimbursable non-NASA metrology work. Investigate the possibility of consolidating metrology for WSTF and WSMR under a single support contract.

Recommendation 2: NASA should maintain materials and chemical analysis capability at WSTF for the near term. Sufficient work is projected for these laboratories over the next few years. A future study to examine consolidating this capability at either MSFC or WSTF may determine that there is potential costs savings in a consolidation. Any future study of this issue must consider the potential negative technical impact to sustaining engineering and required changes to NASA Standard 6001.

Recommendation 3: NASA should retain the High Energy X-Ray Facility at WSTF to support material analysis. NASA should promote this facility and attempt to bring in outside customers to keep the operators proficient and defray costs.

Recommendation 4: NASA should mothball the Liquid Hydrogen Recirculating Pump Test Facility beginning in 2011. SSP specific configuration should be removed to make the facility more attractive for other potential work. If no future work for the facility is identified by 2010, NASA should consider disposing of the facility. For budgeting purposes, NASA should budget no more than operating costs for one year to fund mothballing. The cost to remove the SSP configuration is estimated at $155,000.

Recommendation 5: NASA should begin disposal of the WSTF Low Velocity Impact Test Facility as soon as possible. The equipment utilized in the facility has value to other NASA Centers and Government agencies as well as private testing laboratories. The equipment should be made available first to other NASA centers prior to including on property disposal lists.

Recommendation 6: NASA should consolidate micrometeoroid hypervelocity impact testing at WSTF. Micrometeoroid hypervelocity impact testing capability at other NASA sites should be moved to WSTF or eliminated when the capability is redundant to WSTF capability. Aeroballistic impact testing and planetary impact testing should remain at Ames Research Center.

Recommendation 7: NASA should retain the High Energy Blast Facility but investigate DoD capabilities in this area to determine if NASA could utilize a DoD test facility to meet NASA's requirements for high energy blast testing. If a DoD test facility can meet

NASA's high energy blast testing requirements, the facility at WSTF can be abandoned and the $10,000 - $20,000 annual mothball maintenance costs can be eliminated.

Recommendation 8: NASA should retain the Composite Over-wrapped Pressure Vessel Safety Assessment Test Area at least through the end of the International Space Station Program. The facility should be retained as long as there is sufficient work in this area to support the facility. The capabilities at this facility could potentially support Constellation requirements. Constellation program should investigate using this facility.

Recommendation 9: NASA should utilize the Constellation Propulsion Test Integration Group (PTIG) to conduct trade studies to determine the best solution for testing of Orion Service Module and Command Module Reaction Control Engines. The study should also look closely at future Constellation propulsion testing requirements (LSAM). The study should evaluate capability gaps that exist and how much infrastructure will be needed to fill those gaps. The study should include long term (life cycle) costs such as annual operating and maintenance costs of the infrastructure. Encroachment and impacts on sustaining engineering must also be considered. NASA will not be able to make a decision regarding the 300 and 400 Propulsion Test Areas until the Agency makes a strategic decision on the best approach to complete this type of propulsion testing. If the Agency makes a strategic decision to retain testing capability at the 300 and 400 areas, NASA should consider consolidating small-scale component and subsystem testing (i.e. less than 60klbf) at WSTF to reduce the expense of maintaining component and subsystem test stands at other sites. NASA should use the Rocket Propulsion Test Program to evaluate assigning all small scale work to WSTF.

Recommendation 10: NASA should divest of White Sands Space Harbor beginning in 2011. To meet a schedule of divesting in 2011, NASA should begin interservice agreement termination negotiations in FY 2008. Based on those negotiations, a final divestment budget can be established and demolition design can be initiated in FY 2009 or FY 2010. Any facility demolition required can be started following the last Space Shuttle flight in 2010. NASA should direct Johnson Space Center to begin negotiations with WSMR no later than 2008.

Recommendation 11: NASA should retain the capability to test hypergolic propellant engines and propulsion systems independent of the vendors.

APPENDIXES

A. WSTF Capabilities Mapping Spreadsheet
B. ETIG Facilities Transition Spreadsheet
C. PTIG Facilities Transition Spreadsheet
D. ETIG Impact Test Facilities Summary
E. RPT Facility Utilization Schedule for White Sands Test Facility

Appendix A
White Sands Capability Mapping

Facility Name	ESMD Requirement	Capability at Other Site	Bldg No.	Transition Gap Y/N	Last Need Date	Room No.	Materials Testing to 6001	Analytical Chemistry	Materials and Component Testing with hypergols	Materials Flamability in Oxygen Enriched Atmospheres	High Pres Oxygen Component Testing	Hypervelocity Impact Testing	Composite Overwrapped PV Testing	Space Environmental Simulation	Low Velocity Impact Testing	Large Scale Explosion Testing	Flight Approach Training	Space Communications	Testing of full scale Propulsion Systems	Hypergol Component Repair	WSTF Capabilities from TCB Presentation October 27, 2006	WSTF Core Capabilities from Human Space Flight Capabilities	Description	Usage Description and Rationale	Proposed Government Baseline Sept08	WSTF "Most Likely" Per CEV SSMs June07	"Preliminary" ISS Program Input
Laboratories and Hazardous Test Areas																											
Analytical Chemistry Laboratories			200 200	N	2016+	128, 136A, 136B, 138,& 142 124 & 126	X	X	X	X									X	X	Analytical Chemistry and Metallurgy Laboratories and Materials and Components Testing with Hypergols and Standard Materials Testing per NASA Standard 6001 and Materials Flammability in Oxygen Enriched Atmospheres and Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Analytical chemistry capabilities include: trace metals and organic analysis; thermal, spectroscopic, and specification analysis; custom analysis and services; analysis of samples in a variety of matrices; analytical method development; and instrumentation design and modification. Instrumentation includes FTIR, TGA, TGA-FTIR, DSC including high-pressure DSC, TMA, electrochemical corrosion testing apparatus, and permeation resistance of materials tester.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			ISS is spending ~$70k in FY07; PPBE09 PMR funding requested for FY08 and subsequent years is TBS
Hazardous Fluids (Propellants) – Materials Characterization Laboratory			200	N	2016+	138, 139, 140, 141, 143 & 144	X	X	X										X	X	Materials and Components Testing with Hypergols and Standard Materials Testing per NASA Standard 6001 and Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Stability of energetic materials such as aerospace propellants and interactions of these propellants with the materials used for storage or containment is determined. Capabilities include immersion testing followed by posttest analysis of the fluid and material and propellant decomposition rates, isothermal microcalorimetry, accelerating rate calorimetry measures minimum ignition energy and flammability limits of reactive aerospace liquid fuels are determined.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			No identified ISS funding in FY07-13 based on PPBE09
Large Test System and Test Article Assembly Area			201	N	2016+	South High Bay			X	X	X	X	X		X	X			X		Materials and Components Testing with Hypergols and High Pressure Oxygen Component Qualification Testing and and Materials and Components Testing in High Temperature, High Flow Gaseous Oxygen and Hydrogen and Large-scale Explosion Testing of Propellants	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	This facility is used as a staging area for the buildup of critical test and test support hardware that requires a head clearance space of over 50 feet and protection from external environment. A 15 ton overhead hoist can transition hardware over the entire floor area of the building. At each end of the building, a single 50- by 22-ft lateral sliding door allows large transport vehicle to enter the area. Also includes a Class 10,000 clean assembly area.	This building will be used to support the receiving and staging of critical propulsion hardware and test systems for ESMD and reimbursable projects.			No identified ISS funding in FY07-13 based on PPBE09
Space Environment Simulation and Testing Laboratory			200	N	2016+	130 & 131	X							X					X	X	Space Environment Simulation and Component Repair, Refurbishment, and Testing for Hypergolic Propellants and Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing and Reactive, Explosive, and Toxic Materials Evaluation and Testing	This facility contains a series of chambers ranging from small glass bell-jar chambers to a 10.5 m3 (370 cu. ft.) environmental chamber that can heat and/or cool articles in a vacuum environment. The capability to heat and/or cool in a vacuum allows the support of both standard and nonstandard tests in a simulated space environment. The laboratory is equipped with two helium mass spectrometer leak detectors for finding leaks in high-vacuum and pressurized systems.	These facilities will support the outgassing requirements for both ISS and ESMD. This facility will also provide capability to perform high vacuum thermal test capability for ISS and ESMD hardware.			No identified ISS funding in FY07-13 based on PPBE09
Optical Measurements and Testing Laboratory			200	N	2016+	115			X	X											Materials and Components Testing with Hypergols	Reactive, Explosive, and Toxic Materials Evaluation and Testing and Oxygen Systems Expertise	Provides equipment to perform nondestructive optical testing and measurement of flight, GSE, and developmental hardware. Equipment includes three low vibration/high stability optical benches, light sources and detectors for the IR, UV, and visible regions of the spectra, basic optical components and signal conditioning instrumentation. The laboratory layout provides for access control and shielded areas for the safe operation of high energy light sources.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			No identified ISS funding in FY07-13 based on PPBE09
High Energy X-ray Laboratory			200	N	2016+	117			X		X		X						X	X	Materials and Components Testing with Hypergols and High Pressure Oxygen Component Qualification Testing and Composite Overwrapped Pressure Vessel Safety Assessment Testing and Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Includes 450 kV constant potential x-ray system that can penetrate many aerospace components. Computed tomography imaging system includes an amorphous silicon flat panel array and a gadolinium oxysulfide scintillator (both provide moderate spatial resolution over a large field of view at low x-ray energies) and a terbium-doped borosilicate glass scintillator provides high spatial resolution over a smaller field of view at higher x-ray energies. High-resolution digital camera acquires images from both scintillators.	The operations performed in this facility will support failure analysis and mechanical integrity of components used in ESMD propulsion systems, oxygen and life support systems. CHECK FOR ESMD PLANS. IS THERE WORK AFTER 2010?	Currently used 20% of time doing some CEV shielding studies now. Tends to be used as problems occur. WSTF's system has better resolution than what is available at other facilities.		No identified ISS funding in FY07-13 based on PPBE09
Radiography Laboratory			200	N	2016+	120			X		X		X						X	X	Materials and Components Testing with Hypergols and High Pressure Oxygen Component Qualification Testing and Composite Overwrapped Pressure Vessel Safety Assessment Testing and Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Radiographic techniques include conventional film radiography using half-wave, constant potential, and high-frequency x-ray machines up to 450kV. These x-ray machines are used for examination of components and weldments fabricated from exotic aerospace alloys, up to 7.6 cm (3 in.) of steel equivalent thickness. The image intensifier permits real time radiography for in-motion imaging, while flash radiography is used to study high-speed events, such as ballistics studies.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			No identified ISS funding in FY07-13 based on PPBE09
Metallurgical Laboratory			200	N	2016+	123			X		X		X			X					Materials and Components Testing with Hypergols and High Pressure Oxygen Component Qualification Testing and Composite Overwrapped Pressure Vessel Safety Assessment Testing	Propulsion System Testing and Hypervelocity Impact Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Provides microstructural analysis and mechanical and nondestructive testing including investigation of structural integrity, characterization of materials for material acceptance, welding process and operator qualification, assessment of materials environmental degradation, and failure analysis. Spectroscopic chemical analysis is used to identify alloys, secondary phases such as inclusions and precipitate particles, corrosion products, and other inorganic solids.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			ISS is spending ~$70k in FY07; PPBE09 PMR funding requested for FY08 and subsequent years is TBS

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Appendix A
White Sands Capability Mapping

Facility Name	ESMD Requirement	Capability at Other Site	Bldg No.	Transition Gap Y/N	Last Need Date	Room No.	Materials Testing to 6001	Analytical Chemistry	Materials and Component Testing with Hypergols	Materials Flammability in Oxygen Enriched Atmospheres	High Pres Oxygen Component Testing	Hypervelocity Impact Testing	Composite Overwrapped PV Testing	Space Environmental Simulation	Low Velocity Impact Testing	Large Scale Explosion Testing	Flight Approach Training	Space Communications	Testing of full scale Propulsion Systems	Hypergol Component Repair	WSTF Capabilities from TCB Presentation October 27, 2006	WSTF Core Capabilities from Human Space Flight Capabilities	Description	Usage Description and Rationale	Proposed Government Baseline Sept06	WSTF "Most Likely" Per CEV SSMs June07	"Preliminary" ISS Program Input
Surface Analysis Laboratory			203	N	2016 +	116			X	X	X	X	X							X	Materials and Components Testing with Hypergols and Materials Flammability in Oxygen Enriched Atmospheres and Materials and Components Testing in High Temperature, High Flow Gaseous Oxygen and Hydrogen and Composite Overwrapped Pressure Vessel Safety Assessment Testing and Hypervelocity Impact Testing of Hazardous and Nonhazardous Materials and Assembled Items	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Electron spectrometer use for analysis of top atomic layers of solid samples. Combines techniques of Electron Spectroscopy for Chemical Analysis (ESCA) with Scanning Auger Electron Spectroscopy. Sample pump down and argon ion sputtering are included in the system. This instrument is used in studies that include corrosion, compatibility, contamination, and surface modification which has proven to be beneficial in supporting failure analysis and anomaly investigations.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			No identified ISS funding in FY07-13 based on PPBE09
Offgassing, Odor, and Thermal Vacuum Stability Standard Test Laboratory			203	N	2016 +	107, 140, 141, & 146	X	X						X							Standard Materials Testing per NASA Standard 6001	Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	This facility is used to perform standard NASA-STD-6001 odor and offgassing testing to support all NASA manned space craft. Related consensus methodology testing are also performed such as thermal-vacuum stability testing (SP-R-0022A and ASTM E 595).	The standard NASA-STD-6001 odor and offgassing testing and thermal-vacuum stability testing will be required for ISS and all of the ESMD vehicles.			No identified ISS funding in FY07-13 based on PPBE09
Hazardous Waste Tanks 200 Area			213, 216	N	2016 +		X	X	X	X	X		X	X					X	X	Analytical Chemistry and Metallurgy Laboratories and Materials and Components Testing with Hypergols and Standard Materials Testing per NASA Standard 6001	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Sump and dual tank system for management and disposal of aqueous hazardous waste from the 200 and 800 Area. Can also accept aqueous hazardous waste from throughout WSTF.				No identified ISS funding in FY07-13 based on PPBE09
Gaseous Oxygen, Nitrogen, and Hydrogen High Flow Test Facility			250	N	2016 +	250, 252, 253				X	X									X	Materials and Components Testing in High Temperature, High Flow Gaseous Oxygen and Hydrogen and Component Repair, Refurbishment, and Testing for Oxygen and Hydrogen Systems	Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing and Flight Hardware Repair, Refurbishment, and Certification	Capability for flow testing of components in oxygen, nitrogen, or hydrogen gases at high pressures and flowrates. Oxygen and nitrogen can be heated to outlet temperatures up to 1000 °F. Materials can be tested particles entrained in a flow stream of gaseous oxygen to determine a material's susceptibility to ignition by particle impact. Metal flammability in high pressure, flowing oxygen can be measured with a flowing promoted combustion chamber. Capabilities also include high flow testing of components and sub-systems in liquid oxygen or hydrogen.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			No identified ISS funding in FY07-13 based on PPBE09
Liquid Hydrogen Recirculating Pump Test Facility			253	Y	2009															X	Component Repair, Refurbishment, and Testing for Hydrogen Systems	Flight Hardware Repair, Refurbishment, and Certification	The facility was designed to test the Liquid Hydrogen Recirculation Pump (LHRP) used in the Main Propulsion Subsystem of the Space Shuttle Orbiter to provide flow for chill-down of the vehicle and main engine hydrogen feed systems prior to engine start. The facility consists of a concrete pad, a raised platform on the test pad, a 500 gallon dewar onto which the LHRP is bolted, liquid and gaseous hydrogen piping and control panel, and a data acquisition and control room.	The Space Shuttle's Liquid Hydrogen Recirculation Pump (LHRP) undergoes a series of functional and acceptance tests at cryogenic and ambient conditions. The LHRP manufacturer, Sundstrand Corporation, originally performed the cryogenic acceptance tests at their Perry Lab Facility in Ohio. In 1982, the cryogenic testing was moved to the Energy Systems Test Area (ESTA) at the Johnson Space Center in Houston, TX. In 2001, WSTF was selected to become the new testing location for the cryogenic portions of the acceptance tests.			No identified ISS funding in FY07-13 based on PPBE09
Small Test System and Test Article Assembly Area			255	N	2016 +				X	X	X										Materials and Components Testing with Hypergols and Materials Flammability in Oxygen Enriched Atmospheres and High Pressure Oxygen Component Qualification Testing and Materials and Components Testing in High Temperature, High Flow Gaseous Oxygen and Hydrogen	Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	This facility is used a staging area for the buildup of critical test and test support hardware protection from external environment.	The cryogenic tests were prevQ because of the difference in test stand configurations			No identified ISS funding in FY07-13 based on PPBE09
Low Velocity Impact Test Facility			270	Y	2006										X						Low Velocity Impact Testing	Reactive, Explosive, and Toxic Materials Evaluation and Testing	The Facility is a remote, access-controlled test area capable of launching benign projectiles at relatively non-toxic or non-hazardous targets. The facility has a pneumatic launcher, target stand, digital and high speed cameras. The control room is armored to protect personnel and equipment form stray projectile or target debris. The launcher is a pneumatic, remote operated gas gun with interchangeable barrel sizes and various geometries.		Mothball - hasn't been used in a long term		No identified ISS funding in FY07-13 based on PPBE09

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Appendix A
White Sands Capability Mapping

Facility Name	ESMD Requirement	Capability at Other Site	Bldg No.	Transition Gap Y/N	Last Need Date	Room No.	Materials Testing to 6001	Analytical Chemistry	Materials and Component Testing with hypergols	Materials Flamability in Oxygen Enriched Atmospheres	High Pres Oxygen Component Testing	Hypervelocity Impact Testing	Composite Overwrapped PV Testing	Space Environmental Simulation	Low Velocity Impact Testing	Large Scale Explosion Testing	Flight Approach Training	Space Communications	Testing of full scale Propulsion Systems	Hypergol Component Repair	WSTF Capabilities from TCB Presentation October 27, 2006	WSTF Core Capabilities from Human Space Flight Capabilities	Description	Usage Description and Rationale	Proposed Government Baseline Sept 06	WSTF "Most Likely" Per CEV SSMs June 07	"Preliminary" ISS Program Input
Hazardous Hypervelocity Impact Test Facility			272	N	2016 +				X	X		X	X								Hypervelocity Impact Testing of Hazardous and Nonhazardous Materials and Assembled Items	Hypervelocity Impact Testing	A remote, access- controlled test area capable of simulating micrometeoroid and orbital-debris impacts on spacecraft materials and components. A hazardous fluid handling and disposal network allows toxic, reactive, and explosive targets to be safely evaluated. Release energies up to 2.3 kg (5 lb) TNT equivalent can be accommodated within the facility's sealed target chambers. Five two-stage light gas launchers propel 0.05 to 22.2 mm (1/512 to 7/8 in.) diameter projectiles to velocities in excess of 7.0 km/s (23,000 ft/s). High speed cinema and ultra high speed digital imaging is used record the impact event and flash x-ray imaging to confirm projectile integrity.	The capability is used to perform tests in support of micrometeoroid and orbital debris impact on new spacecraft and shielding materials. The data produced supports analysis and evaluation by the JSC Hypervelocity Impact Technology Group.			ISS PPBE 09 PMR provides funding to this capability through FY10
High Energy Blast Facility			700	Y	2008											X					Large-scale Explosion Testing of Propellants	Reactive, Explosive, and Toxic Materials Evaluation and Testing	Testing with solid, cryogenic, and liquid propellants and with high explosives can be performed with explosive blasts equivalent to 500 lb of TNT. One test area is 300 ft in diameter and contains a ground-zero concrete pad, a 250 ft drop tower, three ground-level instrumentation legs, and three camera bunkers. The second area is 200 ft in diameter and contains three elevated gauge lines. Instrumentation and data acquisition systems are available to obtain side-on and reflected pressure measurements in the far and near field of the reaction and weather information such as wind velocity, humidity, barometric pressure, and ambient temperature.		Hasn't been used much for a few years. Definitly unique to NASA. When needed it is very important. Only takes 10 to 20 K/yr. to keep available. Used last yr for a few weeks by nasa on LOX-Oil explosive TNT equivalent.		No identified ISS funding in FY07-13 based on PPBE09
Materials Flammability in Oxygen Enriched AtmospheresTest Areas			800	N	2016 +	101-113,116, 126,127, 130-132, 830,832, & 834	X			X	X										Materials Flammability in Oxygen Enriched Atmospheres and High Pressure Oxygen Component Qualification Testing	Oxygen Systems Expertise	Determination of ignition susceptibility and flammability testing of materials and components in liquid and gaseous oxygen. Capabilities include upward flame propagation of non-metallics, heat and visible smoke release rates by cone calorimetry, flash point of liquids, wire insulation flammability, impact sensitivity in liquid or gaseous oxygen, sensitivity to pneumatic impact, and promoted combustion of metals in high pressure oxygen.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			ISS PPBE 09 PMR provides low level of funding to this capability through FY16
Standard Materials Test Areas			800	N	2016 +	101, 102, 104, 105, 108, 116, 119, 832	X			X	X		X								Standard Materials Testing per NASA Standard 6001	Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	This facility is used to perform standard NASA-STD-6001 flammability and ignition susceptibility testing to support all NASA manned space craft. Related consensus methodology testing are also performed such as autogenous ignition, limiting oxygen index, and heat of combustion.	The standard NASA-STD-6001 flammability and ignition susceptibility testing will be required for ISS and all of the ESMD vehicles.			ISS PPBE 09 PMR provides low level of funding to this capability through FY??(TBS)
Test Materials Preparation, Staging, and Controlled Access Storage Areas			803 and 804	N	2016 +		X	X	X	X	X	X	X	X	X				X	X	Materials and Components Testing with Hypergols and Materials Flammability in Oxygen Enriched Atmospheres and High Pressure Oxygen Component Qualification Testing and Composite Overwrapped Pressure Vessel Safety Assessment Testing and Hypervelocity Impact Testing of Hazardous and Nonhazardous Materials and Assembled Items	Reactive, Explosive, and Toxic Materials Evaluation and Testing and Oxygen Systems Expertise and Hypervelocity Impact Testing	Extensive capability for preparation of test materials to match actual application methodology in flight hardware fabrication. Also includes storage of batch lot certified materials and non-shelf life sensitive materials as control reference materials for materials test activities.	These capabilities will continue to be required for support of NASA-STD-6001 testing and for control of materials and components for projects for ISS, ESMD, and reimbursable customers.			ISS PPBE 09 PMR provides low level of funding to this capability through FY??(TBS)
High Pressure Test Area			800	N	2016 +	105, 107, 110-113, 130-132, 830, 832, & 834				X	X		X							X	Materials Flammability in Oxygen Enriched Atmospheres and High Pressure Oxygen Component Qualification Testing	Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	The facility has material, component and subsystem test and analytic capabilities for functionality and fluid compatibility in liquid and gaseous oxygen, hydrogen and mixed gases. Testing includes development, qualification, life cycle, off-limit, and destructive testing. Posttest analytic capabilities include component system interactions and component failure analyses, including nondestructive evaluation of component failures and failure modes.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			ISS PPBE 09 PMR provides low level of funding to this capability through FY15
Materials and Components Test Support Buildings			802 and 805	N	2016 +		X		X	X	X		X			X					Materials and Components Testing with Hypergols and Materials Flammability in Oxygen Enriched Atmospheres and High Pressure Oxygen Component Qualification Testing	Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Work shop areas and tool and parts storage to support test systems and test article build up.	These facilities will be used to support ISS, ESMD, and reimbursable projects in the 800 area.			No identified ISS funding in FY07-13 based on PPBE09
Hazardous Fluids Test Area			830	N	2016 +	830, 831, 833, 836-841, 843, 844, 850, & 851	X		X	X	X		X								Materials and Components Testing with Hypergols	Propulsion System Testing and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Testing of materials, components and subsystems for functionality and fluid compatibility in liquid propellants from development, qualification, life cycle testing, off-limit, and destructive testing including capability to perform testing of hypergolic fluids in a vacuum environment.	These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.			No identified ISS funding in FY07-13 based on PPBE09

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Composite Overwrapped Pressure Vessel (COPV) Safety Assessment Test Areas			830, T270 A, T275 A	Y	2012	Test Cells 860 & 862			X		X		X						X		Composite Overwrapped Pressure Vessel Safety Assessment Testing	Reactive, Explosive, and Toxic Materials Evaluation and Testing	Capability for testing of pressure vessels in hydraulic test mode with pressures up to 30,000 psi at defined pressurization rates including testing to burst inside a specially designed blast enclosure that provides for both safety and controlled burst events. Also allows long duration testing of pressure vessel at elevated pressures in either an impact-damaged or manufactured-defect type condition.	Long-term pressurized storage in support of ISS and CEV COPV usage. Propellant - liner compatibility studies for ESMD.	Heavily required for years for		ISS PPBE 09 PMR provides low level of funding to this capability through FY??(TBS)
Hazardous Waste Line			834	N	2016 +		X	X	X	X	X								X	X	Materials and Components Testing with Hypergols	Propulsion System Testing and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Drain line system from 200 and 800 Areas connecting hazardous waste generator areas to the sump and tank system (Hazardous Waste Tanks) final disposition treatment unit.				No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stands and Test Support																											
300 Area Propulsion Blockhouse			300	N	2016 +	102, 103, 115													X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Also known as the 300 area control center. Contains the instrumentation and control systems necessary to conduct hazardous testing in the 300 area, including the operation of all of the test stands in the 300 area and the ancillary support systems (data systems, altitude simulation, photo/video, etc.)	Supports all test control and safety management requirements in the 300 area for test operations for all users.			No identified ISS funding in FY07-13 based on PPBE09
300 Area Propulsion Data Acquisition and Control Terminal Room, Bunker #1 Terminal Room TS 302, 303 & 328, Bunker #2			300, 311, 321	N	2016 +	101													X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	The Propulsion Test Office currently operates the second generation of automated Data Acquisition and Control Systems (DACS). The new systems have proven their merit in tests of Space Shuttle components. Custom control and monitoring software has also been developed and implemented for such applications as safely establishing closed loop startup and shutdown profiles for a liquid propellant rocket engine with turbopump feed system.	Supports all test requirements in the 300 area for data acquisition and control for all users.			No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 301			301	Y	2010														X	x	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Ambient Test stand for propulsion system testing at ambient pressure conditions. Capable of testing up to 60,000 lbf thrust vertically down, or multiple attitude control thrusters in any direction. Hypergolic propellants in place, capable of handling other propellants.	TS301 will be maintained in an active ready to test mode, to support SSP Aft RCS fleet leader testing if required until 2010.	SM RCE development testing. 3rd qtr FY08 thru 2nd qtr FY09	SM Integrated System testing at ambient pressure conditions. (RCE's, AUX engines and OME) Testing August-September 2010	No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 302			302	Y	2005									x					X	x	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 10,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants (currently only equipped with monopropellant hydrazine system). Simulated altitude is maintained during engine firing. Test cell is designed to be capable of testing single engine or entire stage. Can accommodate throttleable engines.	Planned to support Command Module RCE system level propulsion testing.	CM RCE System Level Testing. Simulated Altitude conditions. All of FY10	CM RCE System Level Testing at Ambient pressure conditions; January 2009-January 2010. Potential testing at Simulated Altitude conditions. TS302 chosen to allow for easy transition to altitude tests if decision is made to proceed with these tests.	No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 303 Test Stand Support Building			303, 303A	Y	2010									x					X	x	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to approximately 1000 lbf thrust with monopropellant hydrazine. Other propellants could be utilized, but not currently equipped. Test cell is designed for single thruster only (i.e. not designed for entire stage) firing horizontally. Presently supports Shuttle APU Fleet lead and Delta Qualification testing.	Planned to support Command Module RCE system level propulsion testing.	CM RCE single engine development and qual testing (3rd qtr FY08 thru 2nd qtr FY10) at simulated altitude conditions. CM RCE single engine Acceptance testing (3rd FY10 on out) at simulated altitude conditions	None	No identified ISS funding in FY07-13 based on PPBE09
Fleet Lead Test Article Decommissioning Building			310	N	2016 +														X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Storage and decommissioning of decontaminated Forward and Aft Reaction Control Systems and Orbital Maneuvering System fleet lead test articles until final disposition is established.	After final disposition of decommissioned test article, the building will revert to a test stand support building.			No identified ISS funding in FY07-13 based on PPBE09
Small Altitude Simulation System (300 area) Boiler Building and Water Treatment Building			315, 316	N	2016 +									X					x		Altitude Simulation Systems Using Chemical Steam Generation or Boilers	Propulsion System Testing	Similar to the large altitude simulation system, but on a smaller scale. Uses steam supplied from diesel fired boilers. Supports only TS302 and TS303. Also includes vacuum pumps that can be used to support long duration vacuum soak periods or small (less than 25 lbf) rocket engines.	Supports altitude test requirements for Command module reaction control system. CHECK ESMD REQUIREMENT. Will continue to support SSP APU fleet leader testing through FY2010. Supports testing of full scale propulsion systems at simulated altitude conditions.	Support for CM system level tests at simulated altitude conditions in TS302 and CM single engine tests at simulated altitude conditions in TS303	Support for CM system level tests at simulated altitude conditions in TS302.	No identified ISS funding in FY07-13 based on PPBE09
Test Stand Support Buildings			319, 320	N	2016 +														X		Propulsion System Assembly Areas and Work Shops which Support Testing	Propulsion System Testing	Work shop areas and tool and parts storage to support test stand activities (generally 1 stand support building for every 2 test stands)	These facilities will be used to support ESMD and reimbursable propulsion test activities in the 300 area.			No identified ISS funding in FY07-13 based on PPBE09
Hypergolic Storage, Conditioning, and Distribution System 300 Area			317, 322, 325, 326, 327	N	2008														X		Propellant Storage, Conditioning, and Distribution Capability for Hypergolic Propellants	Propulsion System Testing	A system which provides bulk storage of MMH, hydrazine, and nitrogen tetroxide for distribution to the test stands or for filling of tanks for transportation to the 800 Area Hazardous Fluids Test Area. Propellant systems have the capability to clean up the fluids through filtration and recirculation and to saturate the fluids with nitrogen or helium. Nitrogen tetroxide also can be treated for iron and water removal using a portable molecular sieve unit and enriched with nitric oxide to provide different mixed oxides of nitrogen concentrations. The system also includes a remote oxidizer burner and vent stack and remote fuel scrubber systems to remove propellant vapors from gas streams.	The system will be used to supply hypergolic propellants for ESMD and reimbursable propulsion testing in the 300 area. CHECK ESMD REQUIREMENT. Hydrazine system supports SSP APU fleet leader testing through 2010. MMH/NTO systems support TS328 (Peacekeeper Stafing) until 2011 and TS301 SSP ARCS Fleet leader program until FY2010.	Support for SM RCE testing at TS301.	Support for SM Integrated System testing at ambient pressure conditions.	No identified ISS funding in FY07-13 based on PPBE09

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Appendix A
White Sands Capability Mapping

Facility Name	ESMD Requirement	Capability at Other Site	Bldg No.	Transition Gap Y/N	Last Need Date	Room No.	Materials Testing to 6001	Analytical Chemistry	Materials and Component Testing with Hypergols	Materials Flammability in Oxygen Enriched Atmospheres	High Pres Oxygen Component Testing	Hypervelocity Impact Testing	Composite Overwrapped PV Testing	Space Environmental Simulation	Low Velocity Impact Testing	Large Scale Explosion Testing	Flight Approach Training	Space Communications	Testing of full scale Propulsion Systems	Hypergol Component Repair	WSTF Capabilities from TCB Presentation October 27, 2006	WSTF Core Capabilities from Human Space Flight Capabilities	Description	Usage Description and Rationale	Proposed Government Baseline Sept08	WSTF "Most Likely" Per CEV SSMs June07	"Preliminary" ISS Program Input
Propulsion Test Stand 328			328	Y	2011														X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Ambient test stand for propulsion system testing at ambient pressure conditions. Capable of testing multiple attitude control thrusters in any direction. Hypergolic propellants in place, capable of handling other propellants.	Test stand has been modified from the SSP FRCS fleet lead hot-fire configuration to a configuration that supports the decommissioning of USAF peacekeeper missile 4th stages. Anticipated PK activities until the end of FY2011	None	None	No identified ISS funding in FY07-13 based on PPBE09
400 Area Propulsion Blockhouse			400	N	2016 *	105													X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Also known as the 400 area control center. Contains the instrumentation and control systems necessary to conduct hazardous testing in the 400 area, including the operation of all of the test stands in the 400 area and the ancillary support systems (data systems, altitude simulation, photo/video, etc.)	Supports all LASS operations, test control, and safety management requirements in the 400 area for test operations for all users.			No identified ISS funding in FY07-13 based on PPBE09
400 Area Propulsion Data Acquisition and Control			400	N	2016 *	106, 106A													X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	The Propulsion Test Office currently operates the second generation of automated Data Acquisition and Control Systems (DACS). The new systems have proven their merit in tests of Space Shuttle components, including the improved auxiliary power unit, orbital maneuvering subsystem, aft reaction control subsystem, and a myriad of reaction control thrusters. Custom control and monitoring software has also been developed and implemented for such applications as safely establishing closed loop startup and shutdown profiles for a liquid propellant rocket engine with turbopump feed system.	Supports all test operations in the 400 area for all users.			No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 401			401	N	2016 *									x					X		Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants. Simulated altitude is maintained during engine firing. Test cell is designed to be capable of testing single engine or entire stage. Can accommodate throttleable engines.	Support Service Module Propulsion System and LSAM RCE development, qualification, and acceptance testing. CHECK ESMD REQUIREMENT. IS THERE SCHEDULED WORK AFTER 2010? Air Fore Minuteman 4th stage production quality assurance and aging and surveillance testing is planned through FY2015. This testing uses TS401 resources approximately 2 months every year. However, TS 401 continues to perform testing of development LOX/LCH4 engines at simulated altitude conditions in support of PCAD activities. Planned testing through the end of FY08.	SM Main engine development testing at simulated altitude conditions (3rd qtr FY2009 thru 2nd qtr FY2010). SM OME certification testing at simulated altitude conditions (3rd qtr FY2010 thru 2nd qtr FY2011. LOX/LCH4 devqual/cert testing of cryo OME at simulated altitude conditions (1st qtr FY2011 thru 2nd qtr FY2014). LSAM Ascent engine Dev/qual/APT (3rd qtr FY12 and out)	None. However, TS 401 continues to perform testing of development LOX/LCH4 engines at simulated altitude conditions in support of PCAD activities. Planned testing through the end of FY08.	No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 402			402	Y	2005														X	x	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Ambient Test stand for propulsion system testing at ambient pressure conditions. Capable of testing up to 60,000 lbf thrust. No propellant storage (stage must have propellant supply, or portable supply can be used).		Ambient testing of SM boiler plate Main engine (3rd qtr FY08 thru 2nd qtr FY09). Ambient testing of SM development Main engine (3rd qtr FY09 thru 1st qtr FY10). Ambient development testing of SM Single String Integrated propulsion system (2nd qtr FY10 thru 3rd qtr FY10)	None	No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 403			403	Y	2008									x					X	x	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants (currently only equipped with hypergolic propellant system). Simulated altitude is maintained during engine firing. Test cell is designed to be capable of testing single engine or entire stage. Can accommodate throttleable engines.	Support Service Module and Lunar access module Propulsion Systems development, qualification, and acceptance testing. SSP test needs end in FY07. Planned reimbursable work in Late FY07 and early FY08. Potential CLV roll engine and RCS engine tests in FY10 and FY11.	SM Propellant Storage Device (PSD) development thermal vacuum testing (4th qtr FY08 thru 3rd qtr FY09. SM integrated single string thermal vacuum development testing (4th qtr FY09 thru 3rd qtr Fy10). SM pressurant system and PSD thermal vacuum certification testing (2nd qtr FY10 thru 1st qtr FY11). SM propulsion system Thermal Vacuum qualification tests (3rd qtr FY11 thru 2nd qtr FY12). SM Main engine acceptance testing at simulated altitude conditions (3rd qtr FY11 and out). Flight SM acceptance testing at simulated altitude conditions (2nd qtr FY12 and out)	Integrated system level Development testing of the Crew Launch Vehicle (CLV) 1st stage roll control and Upper Stage Reaction control systems at simulated altitude conditions (4th qtr FY10 thru 1st qtr FY11).	No identified ISS funding in FY07-13 based on PPBE09
Propulsion Test Stand 406			406	Y	2010									x					X	X	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using solid propellants or approximately 3000 lbf thrust with hypergolic propellants. Test cell is designed for single thruster only (i.e. not designed for entire stage) firing horizontally.	Support LOX - liquid methane RCE development and qualification testing.	LOX/Methane RCE single Engine development and qual testing at simulated altitude conditions (1st qtr FY11 thru 2nd qtr FY14)	None	No identified ISS funding in FY07-13 based on PPBE09

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Appendix A
White Sands Capability Mapping

Facility Name	ESMD Requirement	Capability at Other Site	Bldg No.	Transition Gap Y/N	Last Need Date	Room No.	Materials Testing to 6001	Analytical Chemistry	Materials and Component Testing with hypergols	Materials Flamability in Oxygen Enriched Atmospheres	High Pres Oxygen Component Testing	Hypervelocity Impact Testing	Composite Overwrapped PV Testing	Space Environmental Simulation	Low Velocity Impact Testing	Large Scale Explosion Testing	Flight Approach Training	Space Communications	Testing of full scale Propulsion Systems	Hypergol Component Repair	WSTF Capabilities from TCB Presentation October 27, 2006	WSTF Core Capabilities from Human Space Flight Capabilities	Description	Usage Description and Rationale	Proposed Government Baseline Sept08	WSTF "Most Likely" Per CEV SSMs June 07	"Preliminary" ISS Program Input
Propulsion Test Stand 406			406	Y	2010									x					X	X	Testing of Full-scale Integrated Propulsion Systems	Propulsion System Testing	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to approximately 1000 lbf thrust with hypergolic propellants. Test cell is designed for single thruster only (i.e. not designed for entire stage) firing horizontally.	Planned usage for ESMD Program for performing development and qualification testing of the Command Module Reaction Control Engines in FY08-FY10, followed by Command Module RCE acceptance testing from FY10 through end of program. Unless CEV related testing is identified, SSP VRCS engine testing will continue at TS406 until FY10.	SM RCE development testing at simulated altitude conditions. (3rd qtr FY08 thru 2nd qtr FY10). SM RCE certification testing at simulated altitude conditions (3rd qtr FY10 thru 2nd qtr FY12). SM RCE Acceptance testing at simulated altitude conditions (2nd qtr FY10 and out).	None	No identified ISS funding in FY07-13 based on PPBE09
Test Stand Support Buildings			411, 412	N	2016 +														X		Propulsion System Assembly Areas and Work Shops which Support Testing	Propulsion System Testing	Work shop areas and tool and parts storage to support test stand activities (generally 1 stand support building for every 2 test stands)	Building 411 supports all test requirements in test stands 401 and 402 for data acquisition and control for all users and 412 supports test stands 403, 405, and 406.	Supports testing at all 400 area stands		No identified ISS funding in FY07-13 based on PPBE09
Hypergols Storage, Conditioning, and Distribution System 400 Area			414	N	2016 +														X		Propellant Storage, Conditioning, and Distribution Capability for Hypergolic Propellants, Liquid Oxygen, and Hydrocarbons Including Liquid Methane	Propulsion System Testing	A system which provides bulk storage of MMH, hydrazine, and nitrogen tetroxide for distribution to the test stands or for filling of tanks for transportation to the 800 Area Hazardous Fluids Test Area. Propellant systems have the capability to clean up the fluids through filtration and recirculation and to saturate the fluids with nitrogen or helium. Nitrogen tetroxide also can be treated for iron and water removal using a portable molecular sieve unit and enriched with nitric oxide to provide different mixed oxidizer of nitrogen concentrations. The system also includes a remote oxidizer burner and vent stack and remote fuel-scrubber systems to remove propellant vapors from gas streams.	This system will be used to supply hypergolic propellants for ESMD and reimbursable propulsion testing activities in the 400 area.	Supports testing at all 400 area stands		No identified ISS funding in FY07-13 based on PPBE09
Small Altitude Simulation System (400 Area) Boiler Building and Boiler Fuel Storage Building			415, 415A	N	2016 +									X					X		Altitude Simulation Systems Using Chemical Steam Generation or Boilers	Propulsion System Testing	Similar to the large altitude simulation system, but on a smaller scale. Uses steam supplied from diesel fired boilers. Also includes vacuum pumps that can be used to support long duration vacuum soak periods or small (less than 25 lbf) rocket engines. System can be used in conjunction or independently of the Large Altitude Simulation System. Capable of supporting vacuum operations in TS401, 403, 405, and 406.	Provide vacuum support to 400 area test stands for altitude testing of rocket engines for all users.	Supports testing at all 400 area altitude stands		No identified ISS funding in FY07-13 based on PPBE09
Test Article Assembly Area			416	N	2016 +														X		Propulsion System Assembly Areas and Work Shops which Support Testing	Propulsion System Testing	Capability for assembly and checkout of test articles containing hazardous propellants and/or pyrotechnic devices. The facility has a shop and equipment area and a assembly room with a moveable soft-walled Class 100,000 clean room. The assembly room is explosion proof and the floor is dropped approximately 3 in. for spill containment. The assembly room also has a 4000 lb bridge crane.				No identified ISS funding in FY07-13 based on PPBE09
Large Altitude Simulation System - Chemical Steam Generator			481A, 447, 448, 462A, 491A	N	2008									X					X		Altitude Simulation Systems Using Chemical Steam Generation or Boilers	Propulsion System Testing	Provides means to educt both ambient air and rocket exhaust from altitude test stands in order to simulate the vacuum of space for testing rocket engines in a space environment. Uses high volume steam as the motive fluid in a two stage ejector set. System capable of supporting vacuum operations in TS401, 403, and 405.	Supports Altitude Test Stands 401, 403, and 405 with simulated altitude for rocket engine testing. Planned to support ESMD Service Module, Command Module, Lunar Access Module Engine development, qualification and acceptance testing.			No identified ISS funding in FY07-13 based on PPBE09
Inert Gas Storage & Distribution System			500 Area	N	2008														X		Inert Gas Systems Which Support Testing	Propulsion System Testing	Gas storage, compression, and distribution to all of WSTF. Includes nitrogen and breathing air to the entire site and helium to all of the test stands.	Provide breathing air, and inert gas to all of WSTF.			No identified ISS funding in FY07-13 based on PPBE09
Cryogenic Storage System			500 Area	N	2008														X		Support Propulsion Testing	Propulsion System Testing	Storage of cryogenic oxygen and nitrogen for distribution to the test stands.	This system will be used to supply cryogenic oxygen and nitrogen for ESMD and reimbursable propulsion testing activities in both the 300 and 400 areas.			No identified ISS funding in FY07-13 based on PPBE09
Waste Hydrazines Storage, Control Building, Storage Tanks			520, 521, 522	N	2016 +														X		Propellant Storage, Conditioning, and Distribution Capability for Hypergolic Propellants	Propulsion System Testing	Hydrazines contaminated wastewater is stored prior to off-site shipment for final disposal. The facility also contains the entire system inclusive of piping and pump systems that allows for safe and efficient treatment of hydrazines wastewater. The treatment capability is currently not used.				No identified ISS funding in FY07-13 based on PPBE09
Flight Hardware Repair, Refurbishment, and Certification (Depot)			200	N	2016 +	North High Bay														X	Component Repair, Refurbishment, and Testing for Hypergolic Propellants and Bonded Storage and Logistics Areas for Controlled Storage of Critical Hardware and Fabrication Area for Buildup of Test Panels and Support Equipment and Clean Assembly and Disassembly Work Areas	Flight Hardware Repair, Refurbishment, and Certification	Multiple clean rooms, clean-work areas, and bonded storage to support overhaul and repair of space-flight hardware. Can also be used for final assembly of spaceflight hardware. Specifically designed for overhaul and repair of on-orbit propulsion system components ranging from 6000 lbf engines to 25 lbf engines and associated tanks, lines, valves, etc.	ISS requirements for flight hardware refurbishment continue through life of the ISS program. Potential use for ESMD hardware fabrication, integration and checkout.			ISS funding provided through Boeing 10K contract. Amount and phasing is TBS.

White Sands Space Harbor

Appendix A
White Sands Capability Mapping

Facility Name	ESMD Requirement	Capability at Other Site	Bldg No.	Transition Gap Y/N	Last Need Date	Room No.	Materials Testing to 6001	Analytical Chemistry	Materials and Component Testing with hypergols	Materials Flamability in Oxygen Enriched Atmospheres	High Pres Oxygen Component Testing	Hypervelocity Impact Testing	Composite Overwrapped PV Testing	Space Environmental Simulation	Low Velocity Impact Testing	Large Scale Explosion Testing	Flight Approach Training	Space Communications	Testing of full scale Propulsion Systems	Hypergol Component Repair	WSTF Capabilities from TCB Presentation October 27, 2006	WSTF Core Capabilities from Human Space Flight Capabilities	Description	Usage Description and Rationale	Proposed Government Baseline Sept08	WSTF "Most Likely" Per CEV SSMs June07	"Preliminary" ISS Program Input
WSSH Landing Training WSSH Control Tower Operations Control Center Communications Center Runways			T-1000, 1003, 1007, Runways	Y	2010												X				Space Shuttle Pilots Flying Practice Approaches and Landings		The primary training area for space shuttle pilots flying practice approaches and landings in the shuttle training aircraft (STA) and T-38 chase aircraft. The STA provides a realistic simulation of the shuttle's landing from high altitudes to touchdown. The area also provides a wide-open area for various landing configurations, such as parachute or hydrofoil type equipment. The area available for use is 10 miles by 10 miles with additional land available immediately adjacent.	ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for missions returning from the moon).			No identified ISS funding in FY07-13 based on PPBE09
WSSH Shuttle Landing Site WSSH Control Tower Operations Control Center Communications Center Runways			T-1000, 1003, 1007, Runways	Y	2010												X				Contingency Continental US Landing Facilities for Shuttle		WSSH is used as one of three shuttle CONUS backup landing facilities. There are three lakebed runways, two serve as a shuttle backup landing facility. Two of the runways are 35,000 ft by 900 ft, which includes 15,000 ft by 300 ft marked runway with 10,000 ft extensions on either end and 300 ft on either side. The entire area is flat with very few structures. There are very few environmental concerns which interfere with operations and commercial air traffic is restricted from the facility.	ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for missions returning from the moon).			No identified ISS funding in FY07-13 based on PPBE09
WSSH Shuttle Landing Site Vehicle Integration Team Disservice Pad Dispensary Trailer Runways			VIT, 1117, T-1006, Runways	Y	2010												X				Contingency Continental US Landing Facilities for Shuttle		WSSH is used as one of three shuttle CONUS backup landing facilities. There are three lakebed runways, two serve as a shuttle backup landing facility. Two of the runways are 35,000 ft by 900 ft, which includes 15,000 ft by 300 ft marked runway with 10,000 ft extensions on either end and 300 ft on either side. The entire area is flat with very few structures. There are very few environmental concerns which interfere with operations and commercial air traffic is restricted from the facility.	ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for missions returning from the moon).			No identified ISS funding in FY07-13 based on PPBE09
WSSH General Operations WSSH Heavy Equipment Maintenance Maintenance Building WSSH - Hub			1001, 1002	Y	2010												X				Contingency Continental US Landing Facilities for Shuttle		Support for both primary training area for space shuttle pilots and Shuttle CONUS backup landing facilities.	ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for missions returning from the moon).			No identified ISS funding in FY07-13 based on PPBE09
Technical Services																											
Machining and Welding Shop			113	N	2016 +		X	X	X	X	X	X	X	X	X	X			X	X	All	All	White Sands Test Facility maintains a fully integrated 18,000-ft² (1700-m²) fabrication facility with full CNC capability. This is supported by computer-assisted design services.	This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	RPT funds 28% of the work in this facility		No identified ISS funding in FY07-13 based on PPBE09 (ISS use may be derived from other funded services)
Radio Communications Building			119	N	2016 +				X		X						X	X	X		Testing of Fullscale Integrated Propulsion Systems and Materials and Components Testing with Hypergols and High Pressure Oxygen Component Qualification Testing and Materials and Components Testing in High Temperature, High Flow Gaseous Oxygen and Hydrogen	Propulsion System Testing and Oxygen Systems Expertise and Reactive, Explosive, and Toxic Materials Evaluation and Testing	Used as the backup Emergency Operations Center (EOC) in event of a failure in the EOC at bldg 104. Used for monitoring and control of the radio trunking, microwave, and the radio paging systems. Used as operations center for communications personnel to include radio loan pool and test equipment for repair, and certification of communication equipment. Facility also supports the Emergency Communications Base Station.				No identified ISS funding in FY07-13 based on PPBE09 (ISS use may be derived from other funded services)
Photo and Video Test Support			200	N	2016 +	100, 100H, 101,102, 104,105, 107-110, 203, 204	X	X	X	X	X	X	X	X	X	X	X		X	X	All	All	Photo and video imaging functions that include productions of digital photographs, motion picture, and video productions. Services are provided to test projects both in-house and in-field environments, including hazardous areas.	This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	RPT funds 5% of the work in this facility		No identified ISS funding in FY07-13 based on PPBE09 (ISS use may be derived from other funded services)
Fluid Components Laboratory			200	N	2016 +	107, 111, 115, 116, 117	X	X	X	X	X	X	X	X	X	X	X		X	X	All	All	White Sands Test Facility maintains a full-service facility for precision cleaning, repair, re-assembly, and functional testing of fluid components.	This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	RPT funds 10% of the work in this facility		No identified ISS funding in FY07-13 based on PPBE09 (ISS use may be derived from other funded services)
Calibration Laboratories			203	N	2016 +	128, 133, 134, 137, 138, 143,	X	X	X	X	X	X	X	X	X	X	X	X	X	X	All	All	The Calibration Laboratories ensure that the instruments used to make temperature, pressure, load, acceleration, and many other measurements are accurate by calibrating them against recognized standards per NASA Policy Directive 8730.1, "Metrology and Calibration". Facilities include electrical, pressure and pneumatic, force and tool, temperature and humidity, gas and liquid flow, vacuum flow, and dimension and mass calibration capabilities.	This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	RPT funds 11% of the work in this facility		No identified ISS funding in FY07-13 based on PPBE09 (ISS use may be derived from other funded services)

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Appendix B
Environmental Test Integration Group Transition Review

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
113	Machining and Welding Shop		RA	White Sands Test Facility maintains a fully integrated 18,000-ft² (1700-m²) fabrication facility with full CNC capability. This is supported by computer-assisted design services.	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W
119	Radio Communications Building		RA	Used as the backup Emergency Operations Center (EOC) in event of a failure in the EOC at bldg 104. Used for monitoring and control of the radio trunking, microwave, and the radio paging systems. Used as operations center for	SSP	W	W	W	W
					ISS				
					ESMD				
					Institution	W	W	W	W
					Other				
159	Non-hazardous Waste Storage Building		RA	Dome storage building used for holding non-hazardous waste including brass casings for recycle and non-PCB transformers. Also utilized for aerosol can crushing equipment storage.	SSP				
					ISS				
					ESMD				
					Institution	W	W	W	W
					Other				
161	Drum Storage Building		RA	Hazardous waste storage building for drummed waste (<90-day storage only) prior to transport for off-site disposal.	SSP				
					ISS				
					ESMD				
					Institution	W	W	W	W
					Other				

Appendix B
Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
113	W							W: This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	Replace obsolete equipment including Wire EDM, Ram EDM, Clausing Lathe, and Marvel Saw.
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
119	W								
	W	W	W	W	W	W	W		
159									
	W	W	W	W	W	W	W		
161									
	W	W	W	W	W	W	W		

Appendix B
Environmental Test Integration Group Transition Review

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
200	200 Area Depot	North HighBay	RA	Multiple clean rooms, clean work areas, and bonded storage to support overhaul and repair of space-flight hardware. Can also be used for final assembly of spaceflight hardware. Specifically designed for overhaul and repair of on-orbit	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD				
					Institution				
					Other				
200	Photo and Video Test Support Laboratory	100, 100H,101,102,104,105, 107-110, 203. 204	RA	Photo and video imaging functions that include productions of digital photographs, motion picture, and video productions. Services are provided to test projects both in-house and in-field environments. including hazardous areas.	SSP	W	W	W	W
					ISS	W	W	W	W
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W
200	Fluid Components Laboratory	107111115201117	RA	White Sands Test Facility maintains a full-service facility for precision cleaning, repair, re-assembly, and functional testing of fluid components.	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W
200	Analytical Chemistry Laboratories	128, 136A,136B, 138,& 142124 & 126	RA	Analytical chemistry capabilities include: trace metals and organic analysis; thermal, spectroscopic, and specification analysis; custom analysis and services; analysis of samples in a variety of matrices: analytical method	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
200	W							W: ISS requirements for flight hardware refurbishment continue through life of the ISS program. Potential use for ESMD hardware fabrication, integration and checkout.	
	WI	WI	WI	WI	WI	WI	W		
200	W							W: This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	
	W	W	W	W	W	W	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
200	W							W: This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	Purchase new equipment including hydrostat facility, pressure relief device flow tester, and vapor degreaser.
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
200	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	Facility modifications include the repair, replacement and modification of laboratory infrastructure such as fume hood, work stations, chemical storage, and hazardous waste disposal.
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
200	Hazardous Fluids (Propellants) - Materials Characterization Laboratory	136, 139, 140, 141, 143 & 144	RA	Stability of energetic materials such as aerospace propellants and interactions of these propellants with the materials used for storage or containment is determined. Capabilities include immersion testing followed by posttest analysis of the fluid	SSP	W	W	W	W
					ISS				
					ESMD		C	C	C
					Institution				
					Other	W	W	W	W
201	Large Test System andTest Article Assembly Area	South High Bay1351361 37	RA	This facility is used a staging area for the buildup of critical test and test support hardware that requires a head clearance space of over 50 feet and protection from external environment. A 15 ton overhead hoist can transition hardware over	SSP				
					ISS				
					ESMD			C	C
					Institution	W	W	W	W
					Other	W	W	W	W
203	Calibration Laboratories	128, 133,134, 137,138, 143,	RA	The Calibration Laboratories ensure that the instruments used to make temperature, pressure, load, acceleration, and many other measurements are accurate by calibrating them against recognized standards per NASA Policy	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W
203	Space Environment Simulation and Testing Laboratory	130 & 131	RA	This facility contains a series of chambers ranging from small glass bell-jar chambers to a 10.5 m 3 (370 cu. ft.) environmental chamber that can heat and/or cool articles in a vacuum environment. The capability to heat and/or cool in a vacuum allows	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution				
					Other				

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
200	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
201								W: This building will be used to support the receiving and staging of critical propulsion hardware and test systems for ESMD and reimbursable projects.	The upgrade of the overhead hoist will be required to support the offloading of hardware. The hoist will be upgrade to 20 ton capacity
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
203	W							W: This facility will be used to provide services in support of ISS, ESMD, and reimbursable projects as well as institutional activities.	
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
203	W							W: These facilities will support the outgassing requirements for both ISS and ESMD. This facility will also provide capability to perform high vacuum thermal test capability for ISS and ESMD hardware.	
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
203	Optical Measurements and Testing Laboratory	115	RA	Provides equipment to perform nondestructive optical testing and measurement of flight, GSE, and developmental hardware. Equipment includes three low vibration/high stability optical benches, light sources and detectors for the IR, UV, and visible region	SSP	W	W	W	W
					ISS				
					ESMD				C
					Institution				
					Other		W	W	W
203	High Energy X-ray Laboratory	117	RA	Includes 450 kV constant potential x-ray system that can penetrate many aerospace components. Computed tomography imaging system includes an amorphous silicon flat panel array and a gadolinium oxysulfide scintillator (both provide	SSP	W	W	W	W
					ISS				
					ESMD			C	C
					Institution				
					Other		W	W	W
203	Radiography Laboratory	120	RA	Radiographic techniques include conventional film radiography using half-wave, constant potential, and high-frequency x-ray. machines up to 450 kV. These x-ray machines are used for examination of components and weldments	SSP	W	W	W	W
					ISS				
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W
203	Metallurgical Laboratory	123123A,123B	RA	Provides microstructural analysis and mechanical and nondestructive testing including investigation of structural integrity, characterization of materials for material acceptance, welding process and operator qualification, assessment of materials environ	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
203	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
203	W							W: The operations performed in this facility will support failure analysis and mechanical integrity of component used in ESDM propulsion systems, oxygen and life support systems.	
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
203	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
203	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	Chemical fume hoods and mechanical test load frame to allow increased measurement precision, modem data acquisition capability and increased adaptability to project-suitable fixture options.
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
203	Surface AnalysisLaboratory	116	RA	Electron spectrometer use for analysis of top atomic layers of solid samples. Combines techniques of Electron Spectroscopy for Chemical Analysis (ESCA) with Scanning Auger Electron Spectroscopy. Sample pump down and argon ion sputtering are included in	SSP	W	W	W	W
					ISS				
					ESMD		C	C	C
					Institution				
					Other				
203	Offgassing, Odor, and Thermal Vacuum Stability Standard Test Laboratory	107, 140, 141, & 146130, 131Test cell 108, 116	RA	This facility is used to perform standard NASA-STD-6001 odor and offgassing testing to support all NASA manned space craft. Related consensus methodology testing are also performed such as thermal-vacuum stability	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other	W	W	W	W
213	Hazardous Waste Tanks200 Area		RA	Sump and dual tank system for management and disposal of aqueous hazardous waste from the 200 and 800 Area. Can also accept aqueous hazardous waste from throughout WSTF.	SSP				
					ISS				
					ESMD				
					Institution	W	W	W	W
					Other				
250	Gaseous Oxygen, Nitrogen, and Hydrogen High Flow Test Facility		RA	Capability for flow testing of components in oxygen, nitrogen, or hydrogen gases at high pressures and flowrates. Oxygen and nitrogen can be heated to outlet temperatures up to 1000 °F. Materials can be tested particles entrained in a flow stream of gas	SSP	W	W	W	W
					ISS				
					ESMD				C
					Institution				
					Other	W	W	W	W

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
203	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	
	C	C	C	C	C	C	C		
203								W: The standard NASA-STD-6001 odor and offgassing testing and thermal-vacuum stability testing will be required for ISS and all of the ESMD vehicles.	
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
213									Tank liner system replacement or final closure procedures dependent on permitting process.
	W	W	W	W	W	W	W		
250	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	Modernization of data acquisition and control systems; energy efficiency guideline implementation; development of methane storage and testing capability.
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
253	Liquid Hydrogen Recirculating Pump Test Facility		RA	The facility was designed to test the Liquid Hydrogen Recirculation Pump (LHRP) used in the Main Propulsion Subsystem of the Space Shuttle Orbiter to provide flow for chill-down of the vehicle and main engine hydrogen feed systems prior to	SSP	W	W	W	W
					ISS				
					ESMD				
					Institution				
					Other				
255	Small Test System andTest Article Assembly Area		RA	This facility is used a staging area for the buildup of critical test and test support hardware protection from external environment.	SSP	W	W	W	
					ISS				
					ESMD				
					Institution				
					Other	W	W	W	W
270	Low Velocity Impact Test		RA	The Facility is a remote, access-controlled test area capable of launching benign projectiles at relatively non-toxic or non-hazardous targets. The facility has a pneumatic launcher, target stand, digital and high speed cameras. The control room is armor	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
272	Hazardous Hypervelocity Impact Test Facility		RA	A remote, access-controlled test area capable of simulating micrometeoroid and orbital-debris impacts on spacecraft materials and components. A hazardous fluid handling and disposal network allows toxic, reactive, and explosive targets to be safely evalu	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution	W	W	W	W
					Other				

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
253									
255								W: These capabilities will continue to be required for test projects for reimbursable customers and will be available if needed for ESMD.	
	W	W	W	W	W	W	W		
270									
272								W: The capability is used to perform tests in support of micrometeoroid and orbital debris impact on new spacecraft and shielding materials. The data produced supports analysis and evaluation by the JSC Hypervelocity Impact Technology Group. V: Used for MMOD penetration for CEV-ISS suit development/certification as well as mods for lunar suit. Will also	Modification of the two stage light gas guns will be required to meet ESDM and ISS program requirements (ex: launching micro-particles, obtaining higher velocities).
	WI	WI	WI	WI	WI	WI	W		
	C	C	C	C	C	C	C		
	W								

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
300	300 Area Propulsion Blockhouse	102103115	RA	Also known as the 300 area control center. Contains the instrumentation and control systems necessary to conduct hazardous testing in the 300 area, including the operation of all of the test stands in the 300 area and the ancillary support systems (data	SSP	W	W	W	
					ISS				
					ESMD			W	W
					Institution				
					Other				
300	300 Area Propulsion Data Acquisition and ControlTerminal Room, Bunker #1Terminal Room TS 302, 303& 328, Bunker #2	101	RA	The Propulsion Test Office currently operates the second generation of automated Data Acquisition and Control Systems (DACS). The new systems have proven their merit in tests of Space Shuttle components. Custom control and monitoring software has also b	SSP	W	W	W	
					ISS				
					ESMD			W	W
					Institution				
					Other				
301	Propulsion Test Stand 301		RA	Ambient Test stand for propulsion system testing at ambient pressure conditions. Capable of testing up to 60,000 lbf thrust vertically down, or multiple attitude control thrusters in any direction. Hypergolic propellants in place, capable of	SSP	W	W	W	W
					ISS				
					ESMD				
					Institution				
					Other		W	W	
302	Propulsion Test Stand 302		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 10,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants (currently only equipped with monopro	SSP				
					ISS				
					ESMD				W
					Institution				
					Other				

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
300	W	W	W	W	W	W	W	W: Supports all test control and safety management requirements in the 300 area for test operations for all users.	Update 1977 vintage control panels, operator interfaces, and control systems.
300	W	W	W	W	W	W	W	W: Supports all test requirements in the 300 area for data acquisition and control for all users.	Changeover to new signal conditioner system.
301	W								
302	W	W						W: Planned to support Command Module RCE system level propulsion testing.	Add propellant capability (LOX/Ethanol), modify altitude system to provide specific test application, and cost to bring stand out of mothball status.

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
303	Propulsion Test Stand 303Test Stand Support Building		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to approximately 1000 lbf thrust with monopropellant hydrazine. Other propellants could be utilized, but not currently equipped. Test cell is designed for singl	SSP	W	W	W	
					ISS				
					ESMD			W	W
					Institution				
					Other				
310	Fleet Lead Test Article Decommissioning Building		RA	Storage and decommissioning of decontaminated Forward and Aft Reaction Control Systems and Orbital Maneuvering System fleet lead test articles until final disposition is established.	SSP	W	W	W	W
					ISS				
					ESMD				
					Institution				
					Other				
315	Small Altitude Simulation System (300 area) Boiler Building andWater Treatment Building		RA	Similar to the large altitude simulation system, but on a smaller scale. Uses steam supplied from diesel fired boilers. Supports only TS302 and TS303. Also includes vacuum pumps that can be used to support long duration vacuum soak periods or small (le	SSP	W	W	W	
					ISS				
					ESMD			W	W
					Institution				
					Other				
319	Test Stand Support Buildings		RA	Work shop areas and tool and parts storage to support test stand activities (generally 1 stand support building for every 2 test stands)	SSP	W	W	W	W
					ISS				
					ESMD				W
					Institution				
					Other		W	W	W

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
303								W: Planned to support Command Module RCE system level propulsion testing.	Add LOX/Ethanol propellant capability, and modify stand from current IAPU test configuration.
	W	W	W	W	W	W	W		
310	W	W	W					W: After final disposition of decommissioned test article, the building will revert to a test stand support building.	Modify building to accommodate disassembly and storage including containment of low concentrations of propellant vapors.
				W	W	W	W		
				W	W	W	W		
315								W: Supports altitude test requirements for Command module reaction control system.	Install new boiler to upgrade altitude system capability to allow for increased thrust, and multi-axis testing of command module RCE system.
	W	W	W	W	W	W	W		
319	W	W	W					W: These facilities will be used to support ESMD and reimbursable propulsion test activities in the 300 area.	
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
317	Hypergols Storage, Conditioning, andDistribution System300 Area		RA	A system which provides bulk storage of MMH, hydrazine, and nitrogen tetroxide for distribution to the test stands or for filling of tanks for transportation to the 800 Area Hazardous Fluids Test Area. Propellant systems have the capability to clean up t	SSP	W	W	W	
					ISS				
					ESMD			W	W
					Institution				
					Other			W	W
328	Propulsion Test Stand 328		RA	Ambient test stand for propulsion system testing at ambient pressure conditions. Capable of testing multiple attitude control thrusters in any direction. Hypergolic propellants in place, capable of handling other propellants.	SSP	W	W		
					ISS				
					ESMD				
					Institution				
					Other		W	W	W
400	400 Area Propulsion Blockhouse	105	RA	Also known as the 400 area control center. Contains the instrumentation and control systems necessary to conduce hazardous testing in the 400 area, including the operation of all of the test stands in the 400 area and the ancillary support systems (data	SSP	W	W	W	W
					ISS				
					ESMD		W	W	W
					Institution				
					Other	W	W	W	W
400	400 Area Propulsion Data Acquisition and Control	106 106A	RA	The Propulsion Test Office currently operates the second generation of automated Data Acquisition and Control Systems (DACS). The new systems have proven their merit in tests of Shuttle components, including the improved auxiliary power unit, orbit	SSP	W	W	W	W
					ISS				
					ESMD		W	W	W
					Institution				
					Other	W	W	W	W

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
317								W: This system will be used to supply hypergollic propellants for ESMD and reimbursable propulsion testing in the 300 area.	
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
328								W: Test stand is being modified from the SSP FRCS fleet lead hot-fire configuration to a configuration that supports the decommissioning of USAF peacekeeper missile 4th stages.	Removal of test article specific structure, and propellant systems to facilitate installation and use of Peacekeeper fourth stage handling equipment and de-servicing equipment.
	W	W							
400	W							W: Supports all LASS operations, test control, and safety management requirements in the 400 area for test operations for all users.	Update 1963 through 1977 vintage control panels, operator interfaces, and control systems. Update 1991 vintage data acquisition and display systems.
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
400	W							W: Supports all test operations in the 400 area for all users.	Upgrade intercom system to ensure sufficient communications for safe test operations thought test complex.
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
401	Propulsion Test Stand 401		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants. Simulated altitude is maintained du	SSP				
					ISS				
					ESMD	W		W	W
					Institution				
					Other	W	W	W	W
402	Propulsion Test Stand 402		RA	Ambient Test stand for propulsion system testing at ambient pressure conditions. Capable of testing up to 60,000 lbf thrust. No propellant storage (stage must have propellant supply, or portable supply can be used).	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
403	Propulsion Test Stand 403		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants (currently only equipped with hypergo	SSP	W	W	W	
					ISS				
					ESMD		W	W	W
					Institution				
					Other				
405	Propulsion Test Stand 405		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using solid propellants or approximately 3000 lbf thrust with hypergolic propellants. Test cell is designed for single thruster only (i.e. n	SSP	W	W	W	W
					ISS				
					ESMD				
					Institution				
					Other				

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
401								W: Support Service Module Propulsion System and LSAM RCE development, qualification, and acceptance testing.	Replace water cooled turning elbows which have corroded through ~40 years of use. Design and fabricate larger centerbody diffuser required to support CM and LSAM exit diameter. Modify thrust take-out structure to accommodate larger diameter of Cx SM and
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
402									
403								W: Support Service Module and Lunar access module Propulsion Systems development, qualification, and acceptance testing.	Replace water cooled turning elbows which have corroded through ~40 years of use. Design and fabricate larger centerbody diffuser required to support CM and LSAM exit diameter. Modify thrust take-out structure to accommodate larger diameter of Cx SM and
	W	W	W	W	W	W	W		
405	W							W: Support LOX - liquid methane RCE development and qualification testing.	
		W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
406	Propulsion Test Stand 406		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to approximately 1000 lbf thrust with hypergolic propellants. Test cell is designed for single thruster only (i.e. not designed for entire stage) firing horizont	SSP	W	W		
					ISS				
					ESMD			W	W
					Institution				
					Other				
411	Test Stand Support Buildings		RA	Work shop areas and tool and parts storage to support test stand activities (generally 1 stand support building for every 2 test stands)	SSP	W	W	W	W
					ISS				
					ESMD	W		W	W
					Institution				
					Other	W	W	W	W
414	Hypergols Storage, Conditioning, andDistribution System400 Area		RA	A system which provides bulk storage of MMH, hydrazine, and nitrogen tetroxide for distribution to the test stands or for filling of tanks for transportation to the 800 Area Hazardous Fluids Test Area. Propellant systems have the capability	SSP	W	W	W	W
					ISS				
					ESMD			W	W
					Institution				
					Other	W	W	W	W
415	Small Altitude Simulation System (400 Area) Boiler Building andBoiler Fuel Storage Building		RA	Similar to the large altitude simulation system, but on a smaller scale. Uses steam supplied from diesel fired boilers. Also includes vacuum pumps that can be used to support long duration vacuum soak periods or small (less than 25 lbf) rocket	SSP	W	W	W	W
					ISS				
					ESMD			W	W
					Institution				
					Other				

Appendix B
Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
406								W: Planned usage for ESMD Program for performing development and qualification testing of the Command Module Reaction Control Engines in FY08-FY10, followed by Command Module RCE acceptance testing from FY10 through end of program.	Modification to the propellant feed system to meet CM RCE specific pressure and flow-rate requirements. Addition of recirculation and thermal conditioning system for propellant conditioning, and modification to the exhaust duct diffuser and heat exchange
	W	W	W	W	W	W	W		
411	W							W: Building 411 supports all test requirements in test stands 401 and 402 for data acquisition and control for all users and 412 supports test stands 403, 405, and 406.	Changeover to new signal conditioner system.
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
414	W	W						W: This system will be used to supply hypergollic propellants for ESMD and reimbursable propulsion testing activities in the 400 area.	
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
415	W	W						W: Provide vacuum support to 400 area test stands for altitude testing of rocket engines for all users.	Rehabilitate and replace large vacuum pumps used to provide vacuum during preparations for and coast periods between rocket engine test firings.
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
416	Test Article Assembly Area		RA	Capability for assembly and checkout of test articles containing hazardous propellants and/or pyrotechnic devices. The facility has a shop and equipment area and a assembly room with a moveable soft-walled Class 100,000 clean room.	SSP				
					ISS				
					ESMD				
					Institution				
					Other	W	W	W	W
491A	Large Altitude Simulation System - Chemical Steam Generator		RA	Provides means to educt both ambient air and rocket exhaust from altitude test stands in order to simulate the vacuum of space for testing rocket engines in a space environment. Uses high volume steam as the motive fluid in a two stage	SSP	W	W	W	
					ISS				
					ESMD			W	W
					Institution				
					Other	W	W	W	W
500 Area	Inert Gas Storage & Distribution System		RA	Gas storage, compression, and distribution to all of WSTF. Includes nitrogen and breathing air to the entire site and helium to all of the test stands.	SSP	W	W	W	
					ISS	W	W	W	W
					ESMD			W	W
					Institution	W	W	W	W
					Other	W	W	W	W
500 Area	Cryogenic Storage System		RA	Storage of cryogenic oxygen and nitrogen for distribution to the test stands.	SSP	W	W	W	
					ISS	W	W	W	W
					ESMD			W	W
					Institution	W	W	W	W
					Other	W	W	W	W

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Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
416									
	W	W	W	W	W	W	W		
491A								W: Supports Altitude Test Stands 401, 403, and 405 with simulated altitude for rocket engine testing. Planned to support ESMD Service Module, Command Module, Lunar Access Module Engine development, qualification and acceptance testing.	Upgrade control and instrumentation system, and improve reliability as recommended by Mishap Investigation Board.
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
500 Area								W: Provide breathing air, and inert gas to all of WSTF.	Upgrade breathing air, gaseous nitrogen pump and storage capacity to support ESMD workload.
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
500 Area								W: This system will be used to supply cryogenic oxygen and nitrogen for ESMD and reimbursable propulsion testing activities in both the 300 and 400 areas.	
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		
	W	W	W	W	W	W	W		

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Environmental Test Integration Group Transition Review

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
520	Waste Hydrazines Storage Control BuildingStorage Tanks		RA	Hydrazines contaminated wastewater is stored prior to off-site shipment for final disposal. The facility also contains the entire system inclusive of piping and pump systems that allows for safe and efficient treatment of hydrazines wastewater. The trea	SSP				
					ISS				
					ESMD				
					Institution	W	W	W	W
					Other				
650	Plume Front RemediationManifold Building		RA	Building 650 is the Groundwater (Plume-Front) Treatment System (PFTS) that houses the air stripper systems, UV photolysis tower, and associated piping, power supplies, and control systems. Treats contaminated groundwater as part of a long-term (30+ year)	SSP				
					ISS				
					ESMD				
					Institution				
					Other	W	W	W	W
651	Plume Front Injection		RA	Building 651 houses the injection well manifold system that receives treated groundwater from Bldg. 650 and partitions the flow rates out to the injection well systems.	SSP				
					ISS				
					ESMD				
					Institution				
					Other	W	W	W	W
700	High Energy Blast Facility		RA	Testing with solid, cryogenic, and liquid propellants and with high explosives can be performed with explosive blasts equivalent to 500 lb of TNT. One test area is 300 ft in diameter and contains a ground-zero concrete pad, a 250 ft drop tower, three gro	SSP				
					ISS				
					ESMD				
					Institution				
					Other	W			

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Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
520									
	W	W	W	W	W	W	W		
650									Upgrade/addition of treatment system components and installation of associated equipment (IDW treatment unit, air emission control, etc.).
	W	W	W	W	W	W	W		
651									Potential modification to increase components due to additional injection well system requirements.
	W	W	W	W	W	W	W		
700									

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Environmental Test Integration Group Transition Review

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
800	Materials Flammability in Oxygen Enriched AtmospheresTest Areas	101-113,116, 126,127, 130 -132, 830,832, & 834, 119	RA	Determination of ignition susceptibility and flammability testing of materials and components in liquid and gaseous oxygen. Capabilities include upward flame propagation of non-metallics, heat and visible smoke release rates by cone calorimetry, flash po	SSP	WV	WV	WV	WV
					ISS	WIV	WIV	WIV	WIV
					ESMD		C	C	C
					Institution				
					Other	W	W	W	W
800	Standard Materials Test Areas	101, 102, 104, 105, 108, 116, 119, 832103	RA	This facility is used to perform standard NASA-STD-6001 flammability and ignition susceptibility testing to support all NASA manned space craft. Related consensus methodology testing are also performed such as autogenous ignition, limiting oxygen index,	SSP	W	W	W	W
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution				
					Other				
803	Test Materials Preparation, Staging, and Controlled Access Storage Areas		RA	Extensive capability for preparation of test materials to match actual application methodology in flight hardware fabrication. Also includes storage of batch lot certified materials and non-shelf life sensitive materials as control reference	SSP	W	W	W	W
					ISS	W	W	W	W
					ESMD		C	C	C
					Institution				
					Other	W	W	W	W
800	High Pressure Test Area	105, 107, 110 - 113, 130- 132, 830, 832, & 834	RA	The facility has material, component and subsystem test and analysis capabilities for functionality and fluid compatibility in liquid and gaseous oxygen, hydrogen and mixed gases. Testing includes development, qualification, life cycle, off-limit, and de	SSP	WV	WV	WV	WV
					ISS	WIV	WIV	WIV	WIV
					ESMD		C	C	C
					Institution				
					Other	W	W	W	W

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Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
800	VW							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers. V: EVA System Project will need oxygen enriched testing of various components and materials for both development (to determine acceptability of use in design) and for system certification. It is assumed some material research will be	
	W/V	W/V	W/V	W/V	W/V	W/V	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
800	W							W: The standard NASA-STD-6001 flammability and ignition susceptibility testing will be required for ISS and all of the ESMD vehicles. V: EVA System Project will need oxygen enriched testing of various components and materials for both development (to determine acceptability of use in design) and for system certification. It is assumed some material research	
	W/I	W/I	W/I	W/I	W/I	W/I	W		
	C	C	C	C	C	C	C		
803	W							W: These capabilities will continue to be required for support of NASA-STD-6001 testing and for control of materials and components for projects for ISS, ESMD, and reimbursable customers.	
	W	W	W	W	W	W	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
800	VW							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers. V: High pressure oxygen systems are primarily associated with the EVA life support system, which is not reqd until the lunar mission phases. It is assumbed that for those missions (2018), that testing will need to start for the EVA Project approximately 5	
	W/V	W/V	W/V	W/V	W/V	W/V	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
802	Materials and Components Test Support Buildings		RA	Work shop areas and tool and parts storage to support test systems and test article build up.	SSP	W	W	W	W
					ISS	W	W	W	W
					ESMD		C	C	C
					Institution				
					Other	W	W	W	W
830	Hazardous Fluids Test Area	830, 831833, 836 -841, 843,844, 860,and 861	RA	Testing of materials, components and subsystems for functionality and fluid compatibility in liquid propellants from development, qualification, life cycle testing, off-limit, and destructive testing including capability to perform testing of hypergolic f	SSP	W	W	W	W
					ISS				
					ESMD		C	C	C
					Institution				
					Other	W	W	W	W
830	Composite Overwrapped Pressure Vessel (COPV) SafetyAssessment TestAreas	Test Cells860 & 862	RA	Capability for testing of pressure vessels in hydraulic test mode with pressures up to 30,000 psi at defined pressurization rates including testing to burst inside a specially designed blast enclosure that provides for both safety and controlled-burst eve	SSP	W			
					ISS	WI	WI	WI	WI
					ESMD		C	C	C
					Institution				
					Other				
834	Hazardous Waste Line		RA	Drain line system from 200 and 800 Areas connecting hazardous waste generator areas to the sump and tank system (Hazardous Waste Tanks) final disposition treatment unit.	SSP				
					ISS				
					ESMD				
					Institution	W	W	W	W
					Other				

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Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
802	W							W: These facilities will be used to support ISS, ESMD, and reimbursable projects in the 800 area.	
	W	W	W	W	W	W	W		
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
830	W							W: These capabilities will continue to be required for test projects for ISS, ESMD, and reimbursable customers.	
	C	C	C	C	C	C	C		
	W	W	W	W	W	W	W		
830								W: Long-term pressurized storage in support of ISS and CEV COPV usage. Propellant - liner compatibility studies for ESMD.	
	WI	WI	WI						
	C								
834									
	W	W	W	W	W	W	W		

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Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
1007	WSSH COMMUNICATIONS BLDG		RA	UHF System - Goddard, RadioTower & Antennas	SSP	WF	WF	WF	WF
					ISS				
					ESMD			W	W
					Institution				
					Other				
Andre	WSMR Andre Site (Comms)		RA	Shuttle Commsgoes through it	SSP	F	F	F	F
					ISS				
					ESMD			C?	C?
					Institution				
					Other				
	WSSH Landing TrainingWSSH Control TowerOperations Control CenterCommunications CenterRunways		RA	The primary training area for space shuttle pilots flying practice approaches and landings in the shuttle-training aircraft (STA) and T-38 chase aircraft. The STA provides a realistic simulation of the shuttle's landing from high altitudes to touchdown.	SSP	WF	WF	WF	WF
					ISS				
					ESMD				
					Institution				
					Other				
	WSSH Shuttle Landing SiteWSSH Control TowerOperations Control CenterCommunications CenterRunways		RA	WSSH is used as one of three shuttle CONUS backup landing facilities. There are three lakebed runways, two serve as a shuttle backup landing facility. Two of the runways are 35,000 ft by 900 ft, which includes 15,000 ft by 300 ft marked runway with 10,0	SSP	WF	WF	WF	WF
					ISS				
					ESMD				
					Institution				
					Other				

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Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
1007	WF								
	W	W	W	W	W	W	W		
Andre	F								
	C?	C?	C?	C?	C?	C?	C?		
	WF							W: ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for miss	
	WF							W: ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for miss	

Appendix B
Environmental Test Integration Group Transition Review

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
	WSSH Shuttle Landing SiteVehicle Integration Team Disservice PadDispensary TrailerRunways		RA	WSSH is used as one of three shuttle CONUS backup landing facilities. There are three lakebed runways, two serve as a shuttle backup landing facility. Two of the runways are 35,000 ft by 900 ft, which includes 15,000 ft by 300 ft marked runway with 10,0	SSP	WF	WF	WF	WF
					ISS				
					ESMD				
					Institution				
					Other				
	WSSH General OperationsWSSH Heavy Equipment MaintenanceMaintenance BuildingWSSH - Hub		RA	Support for both primary training area for space shuttle pilots and Shuttle CONUS backup landing facilities.	SSP	WF	WF	WF	WF
					ISS				
					ESMD				
					Institution				
					Other				
Delta	Delta Clipper Test Pad		RA	The test pad consists of a 160 x 200 ft. concrete slab and a second 120 x 170 ft. concrete slab located 400 - 500 ft. away. The air space and land access to the area is exclusively controlled by the White Sands Missile Range.	SSP	F	F	F	F
					ISS				
					ESMD				
					Institution				
					Other				

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Environmental Test Integration Group Transition Review

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or
	WF							W: ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for miss	
	WF							W: ESMD has indicated that the CEV testing will be at White Sands Missile Range (WSMR) which will utilize some WSSH capability and that would go until FY12. The possibility also exists of WSSH becoming a permanent landing facility for CEV (probably for miss	
Delta	F								

Appendix C
Propulsion Test Integration Group Transition Capabilities

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
300	300 Area Propulsion Blockhouse	102103115	RA	Also known as the 300 area control center. Contains the instrumentation and control systems necessary to conduct hazardous testing in the 300 area, including the operation of all of the test stands in the 300 area and the ancillary support systems (data	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
300	300 Area Propulsion Data Acquisition and ControlTerminal Room, Bunker #1Terminal Room TS 302, 303& 328, Bunker #2	101	RA	The Propulsion Test Office currently operates the second generation of automated Data Acquisition and Control Systems (DACS). The new systems have proven their merit in tests of Space Shuttle components. Custom control and monitoring software has also b	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
301	Propulsion Test Stand 301		RA	Ambient Test stand for propulsion system testing at ambient pressure conditions. Capable of testing up to 60,000 lbf thrust vertically down, or multiple attitude control thrusters in any direction. Hypergolic propellants in place, capable of	SSP				
					ISS				
					ESMD			C-3	C-3
					Institution				
					Other				
302	Propulsion Test Stand 302		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 10,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants (currently only equipped with monopro	SSP				
					ISS				
					ESMD		C-3	C-3	C-3
					Institution				
					Other				

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or	GAP
300										
300										
301	C-3	C-3						C-3: Contingency Requirement for Orion SM Systems Hot Fire Testing		
302	C-3							C-3: Contingency Requirement for Orion CM Systems Hot Fire Testing		

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
303	Propulsion Test Stand 303Test Stand Support Building		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to approximately 1000 lbf thrust with monopropellant hydrazine. Other propellants could be utilized, but not currently equipped. Test cell is designed for singl	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
310	Fleet Lead Test Article Decommissioning Building		RA	Storage and decommissioning of decontaminated Forward and Aft Reaction Control Systems and Orbital Maneuvering System fleet lead test articles until final disposition is established.	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
315	Small Altitude Simulation System (300 area) Boiler Building andWater Treatment Building		RA	Similar to the large altitude simulation system, but on a smaller scale. Uses steam supplied from diesel fired boilers. Supports only TS302 and TS303. Also includes vacuum pumps that can be used to support long duration vacuum soak periods or small (le	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
319	Test Stand Support Buildings		RA	Work shop areas and tool and parts storage to support test stand activities (generally 1 stand support building for every 2 test stands)	SSP				
					ISS				
					ESMD				
					Institution				
					Other				

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or	GAP
303										
310										
315										
319										

Appendix C
Propulsion Test Integration Group Transition Capabilities

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
317	Hypergols Storage, Conditioning, andDistribution System300 Area		RA	A system which provides bulk storage of MMH, hydrazine, and nitrogen tetroxide for distribution to the test stands or for filling of tanks for transportation to the 800 Area Hazardous Fluids Test Area. Propellant systems have the capability to clean up t	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
328	Propulsion Test Stand 328		RA	Ambient test stand for propulsion system testing at ambient pressure conditions. Capable of testing multiple attitude control thrusters in any direction. Hypergolic propellants in place, capable of handling other propellants.	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
400	400 Area Propulsion Blockhouse	105	RA	Also known as the 400 area control center. Contains the instrumentation and control systems necessary to conduce hazardous testing in the 400 area, including the operation of all of the test stands in the 400 area and the ancillary support systems (data	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
400	400 Area Propulsion Data Acquisition and Control	106 106A	RA	The Propulsion Test Office currently operates the second generation of automated Data Acquisition and Control Systems (DACS). The new systems have proven their merit in tests of Shuttle components, including the improved auxiliary power unit, orbit	SSP				
					ISS				
					ESMD				
					Institution				
					Other				

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or	GAP
317										
328										
400										
400										

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
401	Propulsion Test Stand 401		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants. Simulated altitude is maintained du	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
402	Propulsion Test Stand 402		RA	Ambient Test stand for propulsion system testing at ambient pressure conditions. Capable of testing up to 60,000 lbf thrust. No propellant storage (stage must have propellant supply, or portable supply can be used).	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
403	Propulsion Test Stand 403		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using hypergolic propellants, cryogenic propellants, gaseous propellants and/or hydrocarbon propellants (currently only equipped with hypergo	SSP				
					ISS				
					ESMD				
					Institution				
					Other				
405	Propulsion Test Stand 405		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to 25,000 lbf thrust using solid propellants or approximately 3000 lbf thrust with hypergolic propellants. Test cell is designed for single thruster only (i.e. n	SSP				
					ISS				
					ESMD				
					Institution				
					Other				

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or	GAP
401								C-2: Potential requirement to support Lander Engine Testing		
			C-2	C-2	C-2	C-2	C-2			
402										
403								C-1: Ares I First Stage and Upper Stage RCS Testing per RPT Directives 370 & 371 C-2: Potential Requirement for support to Ares V EDS and Lander programs		
	C-1	C-1		C-2	C-2	C-2	C-2			
405										

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	Facility Name	Room No	Directorate	Description	Program	FY06 Use	FY07 Use	FY08 Use	FY09 Use
406	Propulsion Test Stand 406		RA	Vacuum test cell for propulsion system testing at simulated altitude. Capable of testing up to approximately 1000 lbf thrust with hypergolic propellants. Test cell is designed for single thruster only (i.e. not designed for entire stage) firing horizont	SSP				
					ISS				
					ESMD				
					Institution				
					Other				

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Propulsion Test Integration Group Transition Capabilities

Bldg No.	FY10 Use	FY11 Use	FY12 Use	FY13 Use	FY14 Use	FY15 Use	FY16 - 20 Use	Usage Description and Rationale	Significant Modification or	GAP
406								C-2: Potential requirement to support Lander RCS testing		
				C-2	C-2					

Appendix D
Impact Test Facilities Capabilities

HYPERVELOCITY TEST FACILITY CAPABILITY SUMMARY 1

CENTER	TEST FACILITY/RANGE	TYPE OF LAUNCHER	LAUNCH TUBE DIAMETER(mm)	PROJECTILE DIAMETER(mm)	PROJECTILE VELOCITY (Km/s) RANGE	TARGET SIZE CAPABILITY RANGE (mxm)	LEVEL OF DUPLICATION	FACILITY STATUS	APPLICABILITY TO CONSTELLATION PROGRAM
ARC	Ames Vertical Gun Range	light-gas gun	7.62	10 micron to 7.6mm	3 to 7 km/s	1 by 1	None	operational	cratering of moon/planet surface, MMOD
		powder gun	7.62	10 micron to 7.6mm	0.3 to 3 km/s	1 by 1	None	operational	cratering of moon/planet surface, MMOD
		Air gun	44.7	6.4 to 44.7 mm	0.01 to 0.9 kg/s	1 by 1	Low	operational	cratering of moon/planet surface, MMOD
ARC	Hypervelocity Free-Flight Aerodynamic Facility	Light-gas gun	7.1, 12.7, 25.4, 38.1	3.2 to 38	1.5 to 8.5	1 by 1	None for most bore sizes and target size capabilities.	operational	aero and aerothermodynamic data, MMOD
		Powder gun	20, 44, 61	4.8 to 61	0.5 to 2.0	1 by 1	None	operational	aero and aerothermodynamic data, MMOD
ARC	Hypervelocity Free-Flight Gun Development Facility	light-gas gun	7.1, 12.7, 25.4, 38.1	3.2 to 38	1.5 to 8.5	1 by 1	Low to Moderate	Standby	MMOD
		powder gun	20, 44, 61	4.8 to 61	0.5 to 2.0	1 by 1	None	operational	aerodynamic data, MMOD
		Air gun	25.4	4.8 to 25.4	0.1 to 1.0	1 by 1	None or Low	operational	aerodynamic data, MMOD
MSFC / ITF	Bldg 4612 Micro LGG	2-Stage Light-Gas Gun	2.5	0.01 to 2.5*	2 to 7.5**	1 X 3	None or Low	operational and in use	For MMOD impact testing, Model verification/validation
	Bldg 4612 LGG	2-Stage Light-Gas Gun	12.7, 19.05	2.5 to 19.05	2.5 to 7.5	3 X 6	Low to Moderate on 12.7mm.	Up grading at present	For M/OD impact testing, model verification/validation
	Bldg 4502	Exploding Wire Gun	Variable	Variable	est. to 7-8	opens into room	None	In development	For MMOD impact testing, Model verification/validation
WSTF	RHTL*	2-Stage Light-Gas Gun	.17 caliber (4.32mm)	Any Shape 0.00016mg to 66mg ****	1.5 -7.5 km/s tolerance +/- 0.2 km/s uncertainty 0.6%	Target chamber: 9ft(2.8 m) diameter x 30ft (9.14m) long**, ***	None	Active	MMOD Modeling inputs, Hardware DDT&E validation. Shield design validation, in-flight anomaly investigation
WSTF	RHTL*	2-Stage Light-Gas Gun	.50 caliber (12.7mm)	Any Shape 0.09mg to 1900 mg	1.5 -7.0 km/s tolerance +/- 0.2 km/s uncertainty 1.8%	Target chamber: 5ft (1.52m) diameter x 8ft(2.44m) long	Low based on bore size.	Active	MMOD Modeling inputs, Hardware DDT&E validation. Shield design validation, in-flight anomaly investigation
WSTF	RHTL*	2-Stage Light-Gas Gun	1" (25.4mm)	Any Shape 88mg to 26,000 mg	1.5 -7.0 km/s tolerance +/- 0.2 km/s uncertainty 0.3%	Target chamber: 9ft (2.8m) diameter x 30ft (9.14m) long**, ***	Low based on bore size.	Active	MMOD Modeling inputs, Hardware DDT&E validation. Shield design validation, in-flight anomaly investigation

MSFC Notes:
*theoretically projectiles sizes can be smaller than this if that need arises... dependant on material, etc.
**this gun has been shown to that it can be accelerate projectiles at velocities lower than 2 km/s

WSTF Notes:
*RHTL: Remote Hypervelocity Test Laboratory, Building 272
** Can accommodate Contaminated materials (Hypergolic Fuels, e.g.)
*** Can accommodate Pressurized or Energized Targets
**** Capability to shoot single particles over this entire mass range

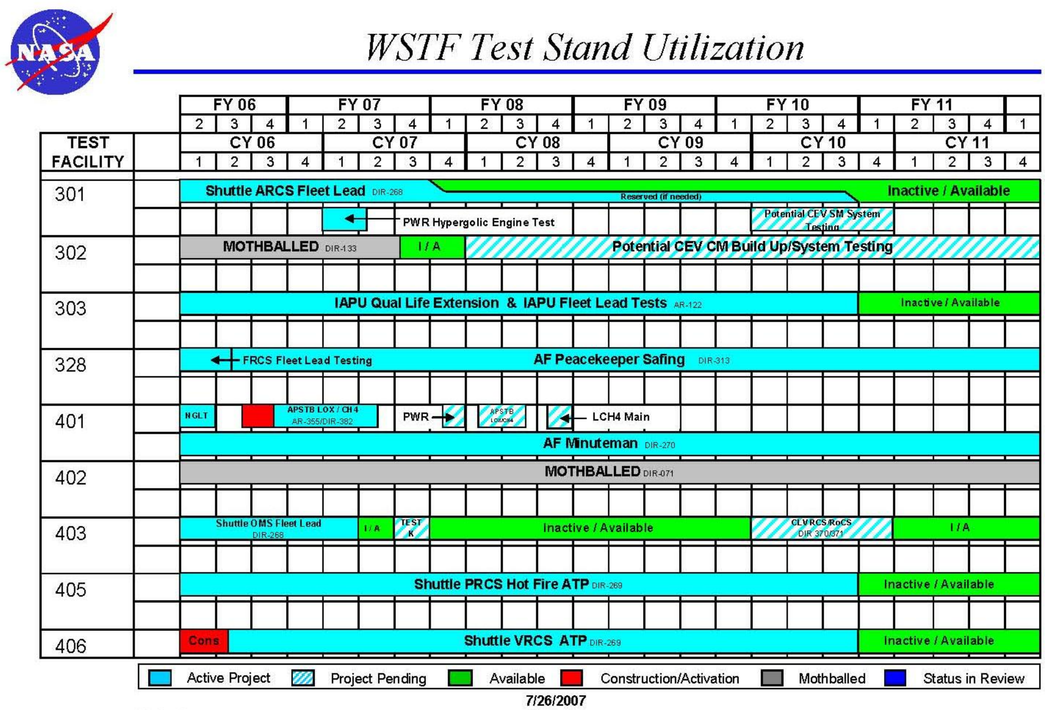
Table Notes: Red and Blue are used to highlight potential capability duplications.
Magenta is used to show that a facility is used for development.

Level of Capabilty Duplication Terminology:
None-No duplication
Low-One other facility has same capability
Moderate-More than one other facility has same capability
High-More than two other facilties have same capability

Appendix E

Rocket Propulsion Test Program (RPT) Facility Utilization Schedule For WSTF Rocket Propulsion Test Stands

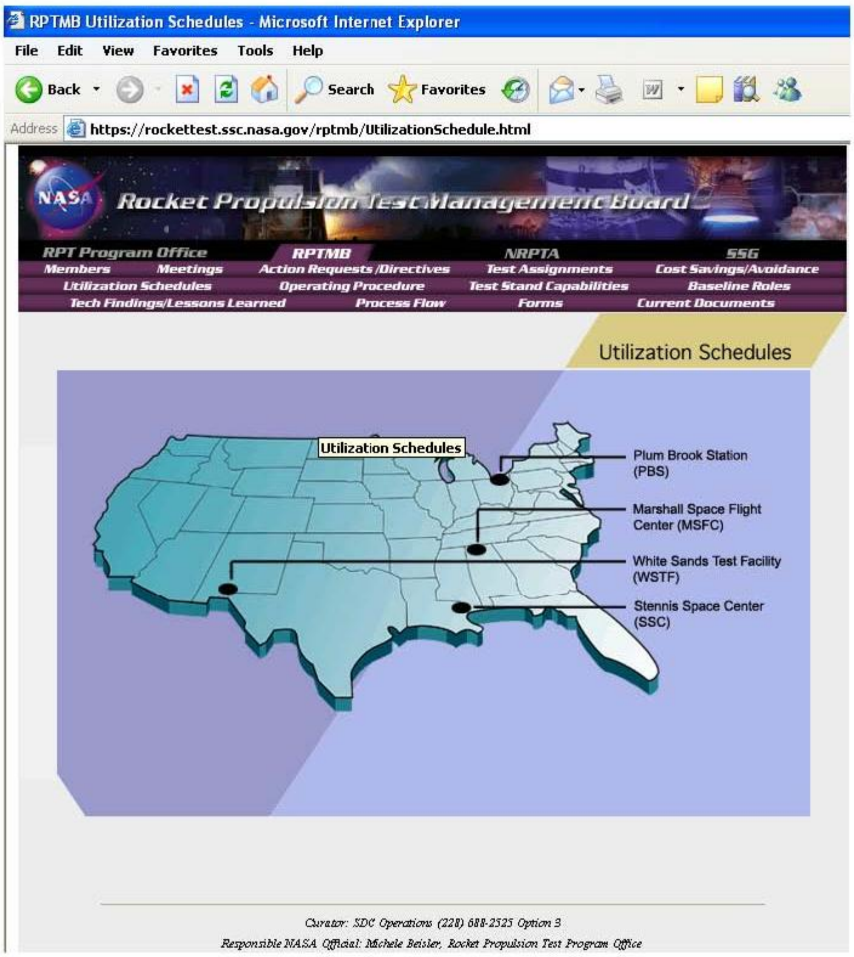
The graphic below represents the commitments for RPT test stands at WSTF.

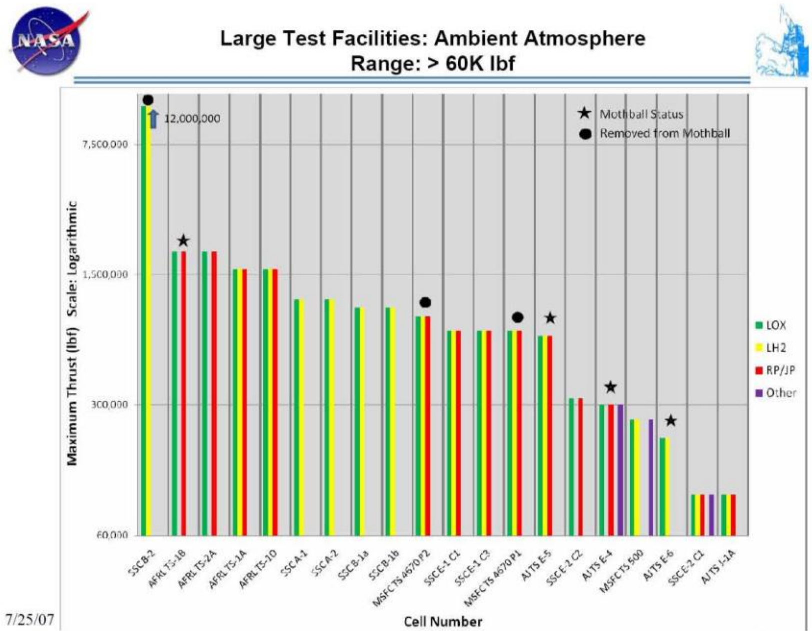


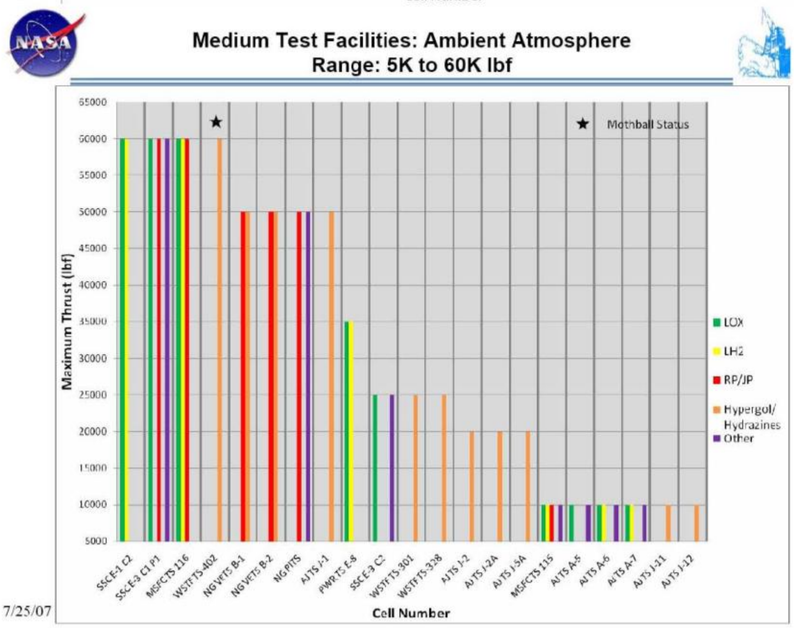
Data Sources:

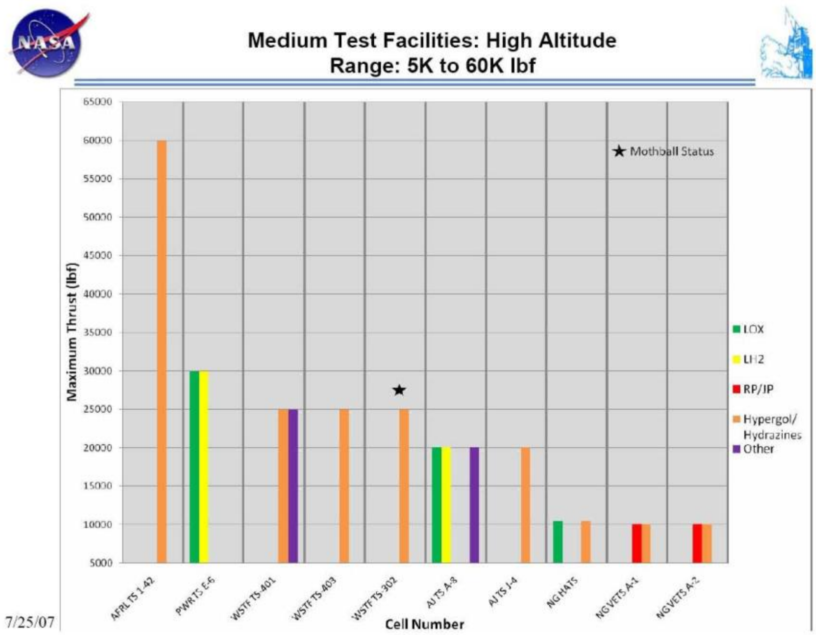
1. RPT PMR Charts, Feb 13-15, 2007
2. RPT Test Stand Utilization Schedules, 5/07
3. WSTF Update, 7/07

RPT utilization schedules are available for all the RPT purview test sites at the program website (screenshot below from -→ https:rockettest.ssc.nasa.gov).




Large Test Facilities: Ambient Atmosphere
Range: > 60K lbf
Maximum Thrust (lbf) Scale: Logarithmic
12,000,000
7,500,000
1,500,000
300,000
60,000
Mothball Status
Removed from Mothball
LOX
LH2
RP/JP
Other
SSCB-2
AFRL TS-1B
AFRL TS-2A
AFRL TS-1A
AFRL TS-1D
SSCA-1
SSCA-2
SSCB-1a
SSCB-1b
MSFC TS 4670 P2
SSCE-1 C1
SSCE-1 C3
MSFC TS 4670 P1
AJTS E-5
SSCE-2 C2
AJTS E-4
MSFC TS 500
AJTS E-6
SSCE-2 C1
AJTS J-1A
Cell Number
7/25/07


Medium Test Facilities: Ambient Atmosphere
Range: 5K to 60K lbf
Maximum Thrust (lbf)
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
Mothball Status
LOX
LH2
RP/JP
Hypergol/ Hydrazines
Other
SSCE-1 C2
SSCE-3 C1 P1
MSFC TS 116
WSTF TS-402
NG VETS B-1
NG VETS B-2
NG PITS
AJTS J-1
PWR TS E-8
SSCE-3 C2
WSTF TS-301
WSTF TS-328
AJTS J-2
AJTS J-2A
AJTS J-5A
MSFC TS 115
AJTS A-5
AJTS A-6
AJTS A-7
AJTS J-11
AJTS J-12
Cell Number
7/25/07


Medium Test Facilities: High Altitude
Range: 5K to 60K lbf
Maximum Thrust (lbf)
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
★ Mothball Status
LOX
LH2
RP/JP
Hypergol/ Hydrazines
Other
AFRL TS 1-42
PWR TS E-6
WSTF TS-401
WSTF TS-403
WSTF TS-302
AI TS A-8
AI TS J-4
NG HATS
NG VETS A-1
NG VETS A-2
Cell Number
7/25/07

Appendix H. Propulsion Risk Reduction Activities for Non-Toxic Cryogenic Propulsion

Propulsion Risk Reduction Activities for Non-Toxic Cryogenic Propulsion

AIAA Space 2010

Timothy D. Smith
Mark D. Klem
Kenneth Fisher

Abstract

The Propulsion and Cryogenics Advanced Development (PCAD) Project's primary objective is to develop propulsion system technologies for non-toxic or "green" propellants. The PCAD project focuses on the development of non-toxic propulsion technologies needed to provide necessary data and relevant experience to support informed decisions on implementation of non-toxic propellants for space missions. Implementation of non-toxic propellants in high performance propulsion systems offers NASA an opportunity to consider other options than current hypergolic propellants. The PCAD Project is emphasizing technology efforts in reaction control system (RCS) thruster designs, ascent main engines (AME), and descent main engines (DME).

PCAD has a series of tasks and contracts to conduct risk reduction and/or retirement activities to demonstrate that non-toxic cryogenic propellants can be a feasible option for space missions. Work has focused on 1) reducing the risk of liquid oxygen / liquid methane ignition, demonstrating the key enabling technologies, and validating performance levels for reaction control engines for use on descent and ascent stages; 2) demonstrating the key enabling technologies and validating performance levels for liquid oxygen / liquid methane ascent engines; and 3) demonstrating the key enabling technologies and validating performance levels for deep throttling liquid oxygen / liquid hydrogen descent engines. The progress of these risk reduction and/or retirement activities will be presented.

Introduction

The PCAD Project's primary objective is to develop propulsion system technologies for exploration missions. The PCAD project is funded by the Exploration Technology Development Program in NASA's Exploration Systems Mission Directorate. PCAD has concentrated its activities on non-toxic or green propellants to meet near term Constellation Program decision gates. Implementation of green propellants in high performance propulsion systems offers NASA an opportunity to consider other options than current hypergolic propellants. The PCAD Project is emphasizing efforts in reaction control system (RCS) thruster designs, ascent main engines (AME) for lunar missions, and descent main engine (DME) for lunar missions. PCAD has developed the following specific objectives:

- Perform cryogenic and non-cryogenic RCS design, ignition testing, and performance testing
- Perform cryogenic ascent main engine design, ignition testing, and performance testing
- Perform cryogenic descent main engine design and performance testing

Liquid Oxygen (LOx) – Liquid Methane (LCH_4) Propulsion

In support of the U.S. Space Exploration Policy for returning to the Moon and beyond, NASA and its partners are developing and testing cryogenic propulsion system technologies that will meet the need for high-performance propulsion systems on long-duration missions. In particular, the lunar ascent module propulsion systems are critical performance drivers, due to the high "gear ratio" (ratio of mass launched to delivered mass to the moon) associated with elements that are utilized through the late phases of the mission. However, due to the relatively small size of the Ascent Module, multiple propulsion system options exist. System trades for both lunar and Mars missions have indicated that LOx/LCH_4 is a promising option, due to the approximate 600-lbm to 800-lbm savings in overall systems mass over more conventional hypergolic systems. Because the Ascent Module is taken to the lunar surface, the indicated mass savings would be converted directly to lunar surface payload. LOx/LCH_4 propulsion for Ascent Main and Ascent/Descent Reaction Control Propulsion is currently conceded as a critical enhancing technology, due to the potential increase of lunar surface payload. The primary technology risks, as determined by the PCAD project team, associated with LOx/LCH_4 propulsion are the following:

1. Reliable/Ignition Pressure Fed LOx/LCH_4 Reaction Control Engines (RCE)
2. Meeting minimum performance and life requirements of LOx/LCH_4 RCE and Main Engines with integrated testing
3. Reliable/Ignition Pressure Fed LOx/LCH_4 Main Engine

The PCAD project focus' on the development of cryogenic propulsion technologies needed to provide necessary data and relevant experience to support informed decisions on potential implementation of cryogenic propellants in the Altair architecture

LOx/LCH_4 Reaction Control Engine Development
Since 2005, the PCAD project has invested in technologies leading to pre-prototype development of LOx/LCH_4 reaction control engines (RCE) with the release of contract request for proposals (RFPs). The focus of the activities were originally to support the Service Module, however in 2006 the activity was steered to support a lunar lander. The top three risks identified for RCE technology are: 1) reliable ignition; 2) Performance (vacuum specific impulse – Isp); and 3) Repeatable pulse width. To address the risks, PCAD undertook a combination of in-house and contract activities.

In 2006 PCAD awarded two RCE contracts to Northrop Grumman and Aerojet respectively. Each contract was focused on the development and delivery of a 100-lbf thrust pre-prototype engine subsystem. The key performance requirements in the contracts were: 1) 317-sec vacuum Isp; 2) 4 lbf-sec minimum impulse bit (Ibit); 3) 80-msec electronic pulse width (EPW); 4) 25,000 valve cycles and 5) operation over a range of inlet conditions from gas to liquid for start. The engine concepts put forward by each company were different in approach to meeting the contract requirements.

Aerojet put forward a concept with foundations in previous work on LOx/Ethanol and internally funded activities. The first engines tested were originally LOx/Ethanol 870-lbf thrusters that were modified to accommodate LOx/LCH_4[1]. The modified units were successfully tested on the Auxiliary Propulsion System Test Bed (APSTB) in NASA White Sands Test Facility (WSTF) Test Stand (TS) 401. The proposed 100-lbf engine concept consisted of a compact integral exciter/spark plug system, a dual coil direct-acting solenoid valve for oxidizer and fuel, an integral igniter and injector, and a columbium chamber/nozzle with an expansion area ratio of 80:1.

Over the course of several contract option periods, multiple injector patterns were developed and manufactured using Aerojet's platelet technology. Flow control for both the main chamber and igniter were controlled by a single set of dual coil valves. The valves were demonstrated to over 55,000 cryogenic cycles in liquid nitrogen, exceeding the 25,000 cycle life. Ignition was accomplished with the use of a spark torch igniter. Over the duration of the contract, a series of igniter and injector concepts were tested at sea level to examine engine performance. The result of the testing was an impinging injector design that successfully met all key performance criteria either by demonstration or calculations based on test data. Aerojet conducted over 1300 engine pulse tests at a variety of duty cycles for over 1900 seconds total of sea level testing during the engine development[2,3]. Specifically Aerojet was able to meet 317-sec Isp calculated based on estimated nozzle losses and exceeded the 80-msec EPW requirement by demonstrating 40-msec EPW. As a result, Aerojet was able to provide 5 engine units to NASA for multiple engines testing on the APSTB at WSTF and 2 units for testing at NASA Glenn Research Center in the Altitude Combustion Stand (ACS).

Sea level[4] and altitude performance testing[5] has been conducted at NASA GRC with the Aerojet engines. A total of 60 altitude hot-fire tests were completed with the Aerojet 100-lb_f liquid oxygen/liquid methane (LOx/LCH_4) engine and propellant conditioning feed systems (PCFS) [6,7]. The PCFS was used to obtain conditions over the range of nominal (204 °R LOx/204 °R LCH_4), cold/cold (160 °R LOx/170 °R LCH_4), to warm/warm (224 °R LOx/224 °R LCH_4). The PCFS uses a combination of cooling loops and heaters to vary the propellant conditions. Test results demonstrated that propellant conditions could be controlled to within +/- 5°R for a given set point. Altitude performance testing was conducted using a 45:1 area ratio columbium radiation cooled nozzle. The main goal of the testing was to develop specific impulse performance curves as a function of mixture ratio. Testing was also conducted over a wide range of propellant inlet conditions (pressure and temperature), to simulate operation in a variety of space environments. The engine demonstrated that meeting the required 317-sec performance is feasible for the 80:1 nozzle based on the results with a 45:1 nozzle.

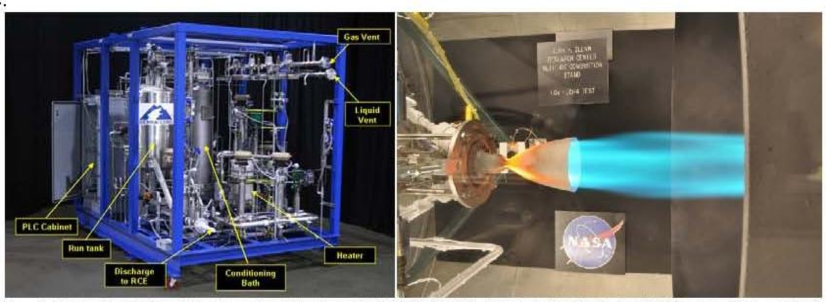


Figure 1 – a) Propellant Conditioning Feed System skid (PCFS); b) Aerojet 100-lbf LOx/LCH_4 reaction control engine in test at NASA GRC

Northrop Grumman put forward a concept with foundations in previous work on hypergol engines. The concept was regeneratively cooled with both oxygen and methane through the combustion chamber and part of the nozzle[8]. The full engine area ratio (120:1) was completed with a columbium nozzle extension. Flow control for both the main chamber and igniter was controlled by a single set of single coil valves. Ignition was accomplished with the use of a spark torch igniter. A series of hardware configurations were tested, starting with workhorse hardware, to develop the engine cooling circuit. During the course of the contract Northrop Grumman ran into a number of design and manufacturing issues which slowed progress. As a result, budget limitations required changes to the scope of the contract which eliminated the planned 4 pre-prototype deliverables. However, Northrop Grumman was able to develop a single pre-prototype unit that was tested in vacuum conditions at their Capistrano test facility. Test results indicate that the engine concept was able to meet the performance specifications in the contract, including exceeding the specific impulse requirement. The measured Isp was approximately 331sec, which exceeded the specification requirement of 317sec. NASA currently has one pre-prototype unit available for further in-house testing.

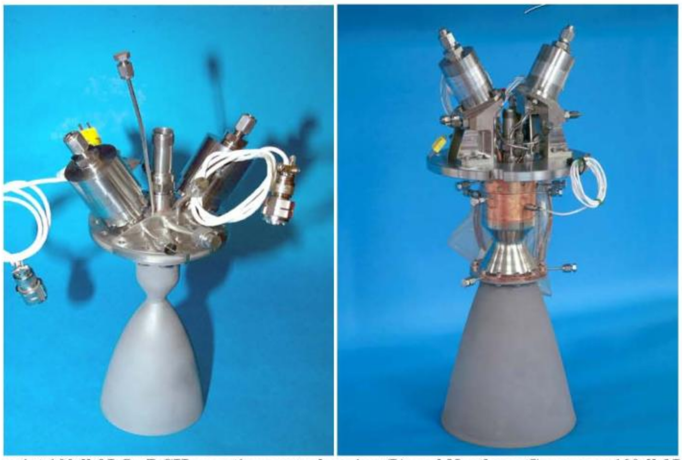


Figure 2 - Aerojet 100-lbf LOx/LCH$_4$ reaction control engine (L) and Northrop Grumman 100-lbf LOx/LCH$_4$ reaction control engine (R)

LOx/LCH$_4$ Reaction Control Engine Integrated Testing

Once developed, the plan was to integrate the RCE thrusters into a four engine cluster which would simulate a vehicle engine configuration. The APSTB was modified with a high vacuum bell jar which serves as the engine cluster simulator. In the bell jar all propellant feed lines and valves were mounted in a way similar to a space craft system. The feed system was also fitted with a thermodynamic vent system (TVS) to condition the propellant delivery to the engines. A total of five engines were delivered from Aerojet for the APSTB testing. Engines were installed and tested at each position. Approximately 2500 pulses were conducted over a sequence of 145 tests. In one test, a total of 380 consecutive pulses were completed. Also, an additional 90 pulses were conducted with two engines firing simultaneously. The engines performed as expected, however the testing did uncover issues with the feed system design. A number of tests suffered from high flow spikes or water hammer which resulted in a number of pressure transducer failures. The data is now being used to develop improvements to feed system models. A complicating factor to the feed system was the APSTB design. Because the rig was originally designed for the Space Shuttle systems development, the rig was significantly oversized. As a result, PCAD has undertaken the development of the Integrated Propulsions System Test Bed (IPSTB). The IPSTB, like the APSTB, will be a propulsion system simulator with propellant tanks, feed lines and an engine cluster. However, the IPSTB will be designed with smaller propellant tanks and with the flexibility to change component locations or vary feed line lengths. The goal of the testing will be to examine system interactions with a number of feed system designs and to obtain the data for comparison with state of the art fluid models. Currently the IPSTB will utilize the current inventory of Aerojet and Northrop Grumman engines.

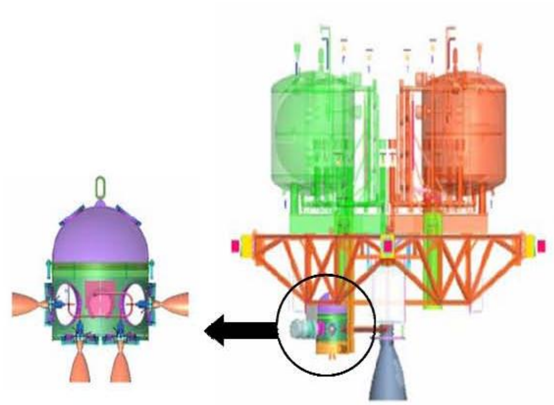


Figure 3 - APSTB at NASA WSTF showing RCE and AME test positions

LOx/LCH_4 Ignition Risk Reduction

To address the highest risk for LOx/LCH_4 propulsion systems, reliable ignition, NASA has conducted numerous in-house experimental efforts to examine the issue. The work has been completed at both RCE and ascent main engine (AME) scales. The majority of the work has been conducted with spark torch igniters[9,10,11,12,13], however there has been work done with microwave[14,15], piezoelectric, spark torch/glow plug combination,[16] and catalytic ignitions systems. Overall there have been no significant issues identified that would prohibit the reliable ignition over a range of conditions with LOx/LCH_4. One of the last ignition specific activities completed was the demonstration of 30,000 ignition cycles on a spark torch ignition system at vacuum conditions[17]. Completion of this activity did not identify any issues with the hardware or designs for long duration applications. The work to date has identified issues with spark plug durability and the reliability of power exciter units. In both cases, PCAD has worked additional technology tasks to address the issues. There appear to be viable solutions in work to reduce the risk.

Figure 4 - LOx/LCH_4 Altitude Ignition Testing at NASA GRC a) Test Cell 21 configuration; b) WASK spark torch igniter during test; c) ascent main engine class igniter during test.

In particular, advancements have been made on the exciter where Aerojet and Unison have developed a single compact exciter[18] unit to replace the current state of the art exciter box and high voltage power lines. NASA has also successfully completed altitude testing with a compact exciter developed under a Small Business Innovative Research (SBIR) Phase II task with Alphaport Inc. Many of the issues remaining with LOx/LCH_4 ignition are related to the specific requirements and duty cycles that will be imposed on the systems or with the final spaceflight qualification of the units. One general area that would still require investigation is ignition in the cold thermal environment of space where both the hardware and propellants have been exposed to those conditions for a significant period of time before being required to operate.

Figure 5 - Prototype Unison compact exciters configured for use with Aerojet 870-lbf RCE

LOx/LCH$_4$ Ascent Main Engine Development

As with RCE, the PCAD project has invested in technologies leading to pre-prototype development of LOx/LCH$_4$ main engine since 2005. The focus of the activities were originally to support the Service Module, however in 2006 the activity was steered to support the lunar lander. The top three risks identified for RCE technology are: 1) reliable ignition; 2) performance (vacuum specific impulse – Isp); and 3) fast start (90% thrust in 0.5-sec). To address the risks, PCAD undertook a combination of in-house and contract activities.

In 2006 PCAD awarded two main contracts to ATK and KT Engineering (KTE) respectively. Each contract was focused on the development and delivery of a 7,500-lbf thrust pre-prototype engine. The key performance targets for the activity were: 1) 7,500-lbf thrust, 355-sec vacuum Isp; 2) 90% rated thrust within 0.5 seconds; 3) total of 24 restarts; and 5) operation over a range of inlet conditions from gas to liquid for start. The engine concepts put forward by each company were different in approach to meeting the contract requirements.

ATK teamed with XCOR to develop a pressure-fed engine concept that was actively cooled with methane[19,20,21]. To enhance the engine life, liquid methane passed through coolant channels machined into the combustion chamber. The warm methane is then injected into the engine where it mixes with liquid oxygen, creating the combustion mixture which provides the engine thrust. As part of the project execution, the ATK/XCOR team developed a "trombone" combustion chamber and injector to conduct early ground testing to examine combustion performance (C* efficiency). The trombone chamber was a water cooled thrust chamber designed to accommodate multiple length configurations to determine an optimum. The data was then used to fabricate a methane cooled workhorse combustion chamber. Sea level testing was conducted with both the trombone and workhorse combustion chambers at XCOR facilities in Mojave, CA.

The second contractor, KTE, chose an ablative combustion chamber in attempts to meet the contract requirements. An ablative material is simply a thick chamber lining that slowly chars away as the engine operates. In this configuration, oxygen and methane are injected into the combustion chamber as liquids. KTE also chose to conduct smaller ignition risk reduction activities at Purdue University on both spark initiated torch igniters (SITI) and catalytic initiated torch igniters (CITI) systems. Both systems were tested successfully at sea level conditions and expected to be used in the larger engines during ground test. As part of the engine development, KTE planned to use a water-cooled combustion chamber for initial injector performance tests. During one of the early tests, the water cooled hardware suffered a catastrophic burn through due to a "hot streak" from the injector. A handful of tests were conducted before the hardware failure. As with the ATK contract, as focus shifted to a lunar lander and NASA did not pick up the options due to the changing requirements.

To meet the new Altair engine requirements, NASA issued a new RFP for a workhorse engine. Work under this contract would primarily be focused with demonstrating the main requirements of 1) 5,500-lbf thrust, 355-sec vacuum Isp; 2) 90% rated thrust within 0.5 seconds; 3) total of 24 restarts; and 5) operation over a range of inlet conditions from gas to liquid for start. However, since the hardware was designated workhorse; weight and certain component developments such as valves, were omitted. From the competitive process, Aerojet was selected as the contractor. Aerojet put forward an ablative engine concept with liquid oxygen / liquid methane injection[22]. The overall activity was broken into two phases. The first phase involved Aerojet fabrication and sea level testing of multiple injector designs. The second phase was NASA taking delivery of the engines and conducting altitude performance testing at NASA WSTF. Under the contract, three injectors were fabricated and tested at Aerojet [23]. A total of 48 tests were completed with both 8-in. and 10-in. length ablative combustion chambers. Most of the tests were conducted at between 10-20 seconds; however, one was conducted at 110-second duration. Performance levels were lower than expected due to excessive film cooling along the combustion chamber wall. To improve performance, two additional injectors were fabricated. The second injector incorporated an alternate injector pattern than the first injector. A total of 7 tests were completed before testing was stopped due to high heat release near the injector face resulting in excessive ablative erosion. Due to heating issues and low overall performance, this injector was not a viable candidate for altitude testing. The third injector was an iteration of the first injector, only with a lower percentage of film coolant. Testing was cut short due to excessive heating at the injector face.

Testing at NASA-WSTF proceeded with the first injector from the Aerojet AME contract. While the sea level testing performance levels were lower than desired, it was felt the altitude testing could still provide useful information. In particular, the team was interested in developing a correlation between the sea level results and altitude tests. The tests results would also provide key data to use in validating nozzle performance analysis, including quantifying potential loss parameters. Testing[24] was conducted with an 8-inch long ablative combustion chamber and a radiation cooled columbium Space Shuttle OMS-E nozzle extension, which provides an area ratio of 129:1. Design area ratio for the vision prototype engine design is 150:1. A total of 187 seconds of run time was achieved on the engine including seven 20-sec tests and one 40-sec test. The injector, chamber and nozzle were all in good physical condition after the testing. Calculated vacuum specific impulse numbers for the test program averaged approximately 344 lb_f-sec/lb_m and peaked at 345.3 lb_f-sec/lb_m with the 129:1 area ratio OME nozzle. Extrapolating to 150:1 conceptual flight design point a Isp~ 348-sec could be achieved. This is within 2% of the target. This result higher than expected based on pretest predictions from the sea level test results. Predictions were done with the well characterized Two Dimensional Kinetics (TDK) computer code. Characteristic exhaust velocity efficiencies were estimated to be between 94 and 95%.

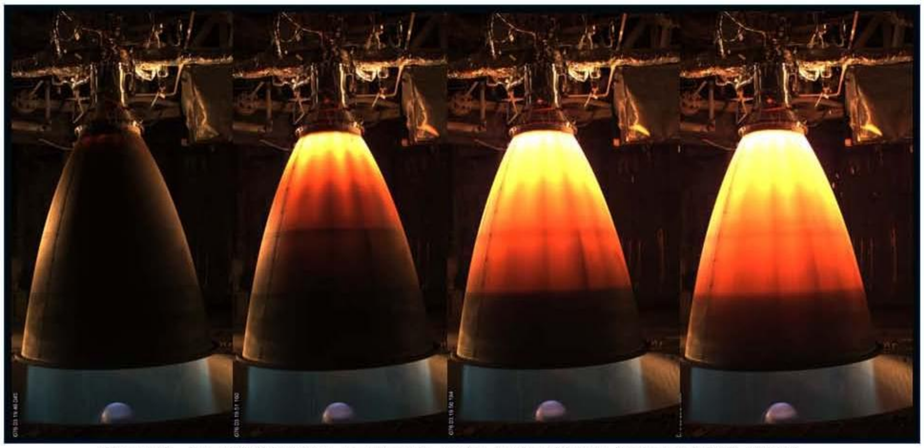


Figure 6 - Aerojet LOx/LCH$_4$ ascent main engine during altitude testing at NASA WSTF

LOx/LCH$_4$ Ascent Main Engine Component Development

In parallel to the contract efforts, NASA conducted in-house injector development on oxygen/methane injectors. Tests were conducted on both 2-in diameter and 6-in diameter chambers at NASA MSFC[25,26,27,28,29]. Testing has been focused on the performance and stability characteristics of a swirl coaxial injector with multiple combustion chamber lengths. The in-house tests have been able to demonstrate 98%+ C* efficiencies with a 20-in long combustion chamber. The testing has also collected heat transfer data with use of a water cooled combustion chamber; combustion stability data for model comparison; and chamber length correlations to obtain performance levels. In addition, work has been successful in demonstrating microwave and spark torch ignition systems in sea level and altitude tests.

Figure 7 - LOx/LCH$_4$ injector sea level test at NASA MSFC

A pressure fed methane regeneratively cooled engine could be used to meet a lunar lander mission. One area identified from the ATK testing is flow instabilities in the coolant channels with methane at subcritical conditions. NASA is conducting in-house experiments[30] with a heated tube facility to simulate a methane coolant channel to examine flow stability and characterize heat transfer properties.

To address the key risk of a main engine ignition at vacuum and to provide a pathfinder engine for WSTF altitude testing, NASA and Pratt&Whitney Rocketdyne (PWR) tested an unmodified RS-18 engine with LOx/LCH$_4$ and a spark torch igniter, in altitude conditions at NASA White Sands Test

Facility TS401[31]. Because the injector was not modified from the original configuration used for the hypergolic propellant combination of NTO/Aerozine 50, it was not expected to provide a high C* efficiency. However, 3 successful main engine vacuum ignitions were conducted which met the main objective of the test.

In conjunction with the Innovative Partnership Program (IPP) and PCAD, work began at the NASA Johnson Space Center with Armadillo Aerospace on the testing of a 1,500-lbf thrust-class LOx/LCH$_4$ rocket engine[32,33]. Sea level testing was conducted at the Armadillo facilities in Caddo Mills, TX and simulated altitude tests were conducted at NASA WSTF. Testing examined engine performance and ignition, both gas torch and pyrotechnic, at altitude conditions. The rocket engine was designed to be configured with three different nozzle configurations, including a dual-bell nozzle geometry. A total of 10 hot-fire ignition and dual-bell nozzle tests were conducted at NASA WSTF.

Figure 8 - LOx/LCH4 engine testing at NASA WSTF. a) PWR RS18; b) Armadillo Aerospace dual bell nozzle engine

Liquid Oxygen (LOx) – Liquid Hydrogen (LH$_2$) Propulsion

One of the mission enabling technologies to support future lunar missions is the development of a liquid oxygen – liquid hydrogen (LH$_2$) deep throttling descent engine. The descent main engines must be able to throttle and remain controlled by the crew to provide a soft landing or to maneuver to a different landing site. Rocket engines typically have a fixed point design that does not allow power levels to throttle over a wide range of operating conditions. If not designed properly, throttling a rocket engine can create low frequency instability in engine pressure, which can cause a reduction in performance or even damage to the engine or vehicle. As currently defined, deep throttling for the lunar missions is a 10:1 ratio, or an engine that can stably throttle from 100% to 10% power. The PCAD project is exploring three options through contracted efforts to develop deep throttling technologies. The first is with the Common Extensible Cryogenic Engine (CECE)[34], a modified RL10 from Pratt&Whitney Rocketdyne (PWR). A second effort is technology development for an expander cycle engine with Northrop Grumman Aerospace Systems (NG) based on the Pintle injector. The third option is a throttling injector concept being developed by Aerojet. Along with the contracted efforts, NASA is exploring in-house technology efforts with the development of an expander cycle test bed at NASA Marshall Space Flight Center (MSFC).

Descent Engine Technology Contracts

The CECE contract with PWR was initiated in July 2005 with the development of the Demo 1.0 activity. The primary focus of Demo 1.0 was to assemble a deep throttling technology demonstrator from existing expander cycle RL10 parts. A number of key components were changed to develop the demonstrator including the fabrication of a fixed-geometry, high pressure drop injector, change out of turbine bypass (TCV) and oxidizer control valves (OCV), adding a larger turbine bypass valve (TBV), and a variable area cavitating venturi (VACV).

The first test series, Demo 1.0, completed four test runs between April and May 2006 at the PWR E6 facility in West Palm Beach, FL. The testing was able to obtain baseline performance and stability data from 20% to 90%. To meet the requirements, testing was completed down to 10% power. However, at 16% power, lower power chugging oscillations were detected. Despite the chugging the tests were successful because it quantified the baseline operating boundaries and provided valuable data to update performance and operations models. It was determined from the data analysis[35] that the chugging was the result of vapor formation in the injector oxygen manifold. A second series of tests, Demo 1.5, were conducted in March and April 2007 with the same engine configuration as Demo 1.0. A total of four tests accumulated a total of 1162 seconds of run time. The testing explored the boundaries of the chug instability over a range of mixture ratios and chamber pressures. During the testing additional technology challenges were identified, in particular, 1Hz instability in the fuel system due to film boiling at low power. There was also a 4000 Hz, 1T combustion oscillation observed between 30-40% power. Testing was also conducted at throttle rates from 100 percent/sec down to 2.5 percent/sec. Overall the Demo 1.0 and Demo 1.5[36] testing developed a wide ranging set of baseline performance data down to 10% power and identified key technology needs for future efforts.

The Demo 1.6[37] test campaign was designed to evaluate mitigations for the low frequency combustion instability ("chug") observed at low power conditions during the Demo 1.0 and Demo 1.5 test programs. To eliminate the oxygen manifold film boiling, a new injector was designed which incorporated a thermal barrier coating on oxygen side of the inner propellant plate. The goal was to reduce the heat transfer from the warm hydrogen into liquid oxygen and prevent the film boiling. To mitigate the chug, the Demo 1.6 injector was modified from the previous configurations to include a spray-on insulation to reduce heat transfer to the LOx manifold, which was believed to be a significant contributor to the low power instability. In addition, gaseous helium injection into the LOx manifold was used as a means to stabilize the system. Also explored in this test series was mitigation for a low power 1 Hz fuel system oscillation caused by sub-critical hydrogen boiling in the chamber cooling jacket. Reduced area gas venturis were utilized to avoid the 1 Hz fuel-size oscillation by keeping the cooling jacket supercritical down to lower engine power levels.

The final test of the CECE engine, Demo 1.7[38] was designed to test the ability of starting the engine at low power and to demonstrate closed loop control of a throttling engine. Demo 1.7 testing[39] successfully demonstrated a number of engine modes of operation including chamber pressure and mixture ratio closed-loop control over a wide range of throttled power levels, fast throttle ramp rates, minimum power down to a smooth start to 10% power, eleven rapid relights demonstrated (many achieved as 2 relights within the same test matrix run), and high power, high mixture ratio operation. Finally the testing demonstrated low power stability, including chug-free operation down to 5.9% power. This represents a 17.6:1 overall cryogenic deep throttling ratio in a complete expander cycle engine system with all system-level interactions which greatly enhanced the value of the technology database acquired. Total Demo 1.7 engine testing has concluded with a total run time of 2,403.0 seconds (40.0 minutes). Total CECE demonstrator engine run time has concluded with 7,435.8 seconds (123.9 minutes).

Figure 9 - PWR CECE during altitude testing in PWR E6 test stand.

The second contracted effort developing deep throttling LOx/LH_2 engine technologies is with Northrop Grumman Aerospace Systems (NGAS) on the TR202 contract[40,41]. The work with NGAS was started in June 2005 and is also focused on an expander cycle engine. The focal point of the NGAS engine concept is the variable area pintle injector, which is similar to the injector used on the Apollo Lunar Module Descent Engine. The first phase of the contract was focused on the design and development of a test-bed pintle injector. The injector design has a oxidizer centered pintle where the oxygen flows through a central passage and is injected radially through individual orifices into the combustion chamber. The fuel is injected through an annular sleeve around the center pintle post. The fuel creates a sheet that impinges with the radial oxygen flow. The injector throttling is controlled by articulating the fuel sleeve along the length of the pintle to either increase or decrease the oxygen flow area. For a flight engine the sleeve would be controlled by an actuator based on throttle inputs from the flight profile. For ground testing the fuel sleeve/throttle position did not have a position actuator.

Testing was conducted with both ablative and water cooled combustion chambers[42,43]. The ablative chamber test series encompassed 22 tests at a nominal mixture ratio of 6, and thoroughly explored injector momentum rate ratio design space; confirmed expectations for excellent high performance potential over the high-end of the throttle power range; demonstrated stable deep-throttle combustion performance at 25% and 10% power conditions; and, validated the thermal integrity of the hardware design. A total of six Pintle configurations were tested using two fuel injection ring sizes. The ablative chamber test series yielded sufficient understanding and confidence in the injector design to justify change over to calorimeter chamber hardware, which enables accurate determination of performance and heat transfer characteristics in a follow-on test series. Testing with the calorimeter was successful in meeting all primary and secondary technical objectives including high performance (>98% C* (combustion) efficiency); stable 10:1 deep throttling; measurement of heat transfer characteristics; evaluation of off-nominal oxidizer to fuel mixture ratio (MR) sensitivities; and evaluation of L* sensitivity. The majority of the test program was devoted to an extensive Design of Experiments

(DOE) for optimized injector performance in which the major influencing parameters were characterized. After extensive testing, the team arrived at an optimized high-performance injector design. Testing of the optimized injector demonstrated stable combustion over the full 10:1 throttle range, and heat transfer characteristics were within anticipated ranges.

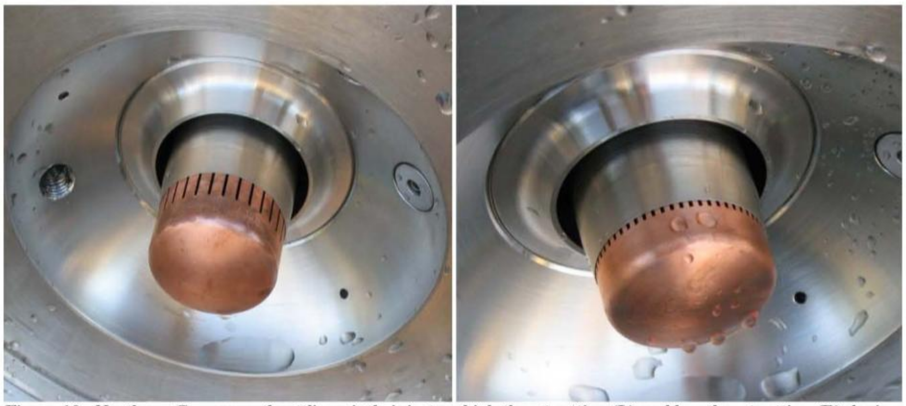


Figure 10 - Northrop Grumman throttling pintle injector: high thrust setting (L) and low thrust setting (R) during water flow testing

In 2009, Aerojet was also awarded a contract to develop deep throttling injector[44] technologies. The contract builds upon an internal research project the company conducted to demonstrate 10:1 throttling with a 1,500-lbf injector[45]. The current effort will focus on 10:1 throttling with a 9,000-lbf thrust injector. The engine system envisioned is an expander cycle LOx/LH_2 engine. The injector is anticipated to be sea level tested in 2011 with a hydrogen regenerative cooled combustion chamber supplied under a Space Act.

NASA In-House Component Development

NASA is conducting several complementary component development activities in-house. Development of the in-house technologies will be conducted on the Lunar Lander Descent Engine Testbed (LLDETB) on Test Stand 500 at NASA MSFC. This sea-level rig is a flexible system to accommodate change out of injectors, combustion chambers, and turbomachinery. As part of the test rig build-up a number of individual components have been fabricated and tested independently. One of the first components tested was a dual oxygen–inlet swirl coaxial element deep throttling injector[46]. The dual-inlet injector has two fixed area oxygen manifolds to maintain sufficient pressure drop across a wide range of throttle conditions. Each manifold has fixed inlet areas to the oxygen posts of the injector and flow can be independently controlled with shutoff valves. For high power cases oxygen would flow through both manifolds, however at low power, flow to the secondary manifold would be cut off. The tests provided all data needed to calculate C* efficiency, heat flux, and other information such as high speed pressure data[47]. The injector achieved very high C* efficiency numbers and stable operation at the high power levels. There were some low frequency (chug) instabilities at the lower power levels. These chug modes are currently being attributed to the LOx supply temperatures which were warmer than ideal. Results from the testing will contribute to future development of a two-stage injector concept or any deep throttling technology.

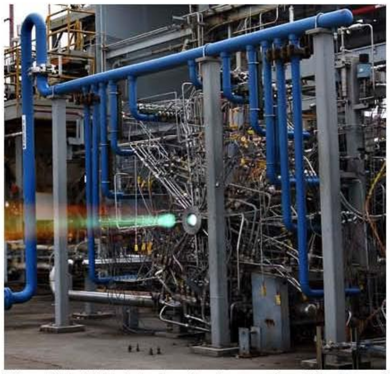


Figure 11 - NASA two-stage throttling LOx/LH_2 injector during sea level testing with water cooled calorimeter at NASA MSFC

An important technology in the control of deep throttling engines is the ability to control the cooling flow from the combustion chamber to the fuel turbo pump. To examine improved control, work under an Innovative Partnership Program (IPP) with Vacco Industries developed an advanced turbine bypass valve (ATBV). The goal of testing was to determine the effective flow area versus valve position at nine equally spaced points in the valve travel and exercise the valve under engine conditions to examine seal performance. The test program consisted of two tests series to determine the flow coefficient versus position and evaluate the ATBV design while operating in simulated engine temperature, flow rate, and pressure conditions. The team was also able to operate the valve in various simulated engine environments to fully characterize the performance of the ATBV design.

Figure 12 - ATBV during performance testing at NASA MSFC

Conclusion

The Propulsion and Cryogenic Advanced Development (PCAD) Project Team led by NASA Glenn Research Center (GRC) in partnership with Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), White Sands Test Facility (WSTF), and industrial partners, is conducting a focused technology development effort to advance high performance cryogenic propulsion systems. Over the last five years this team has been a model for cross center collaboration. To date the team has made great strides in reducing the primary risk of LOx/LCH_4 ignition. At the beginning of PCAD, concerns were expressed that the ignition of LOx/LCH_4 was not feasible. However, with a combination of in-house and contractor activities, the PCAD team has shown that LOx/LCH_4 can be reliably ignited over a wide range of conditions. Also, under contract, PCAD has demonstrated that reaction control engines can be developed to the pre-prototype level which meets mission requirements. Due to the nature of pulsed operation, it can be argued that the LOx/LCH_4 reaction control engine was the most challenging problem facing the team. However, despite the team's successes, new challenges have arisen during the course of the project. For the reaction control engines, system interactions and operations in a cluster proved to be difficult. The engine and flow system operation were sensitive to system design and operation, hence the requirement to move forward with the Integrated Propulsion System Test Bed (IPSTB). There is also still individual work to be done with the reaction control engines with additional vacuum testing. Much of the performance work was done at sea level at single set point flow inlet conditions. PCAD is planning to do extensive testing to evaluate engine performance across a wide range of propellant inlet pressure and temperatures. Testing will also be conducted to simulate the hot and cold variations the engine will see during space operations.

The ascent main engine has not had as much success as the reaction control. While the RCE work has done much to reduce the risks associated with the propellant combination, ultimately it is the performance of the ascent main engine which will determine if LOx/LCH_4 is a viable candidate for the lunar ascent vehicle. Based on the system studies, the success is tied to the ability to demonstrate the highest level of vacuum specific impulse, with 355-sec being the current target. The amount of weight savings to the vehicle is directly tied to the Isp level achieved by the main engine. A lower specific impulse will result in a lower mass savings for the LOx/LCH_4 option versus the current hypergolic baseline. The current effort with the Aerojet design is to see just how close the team can get a main engine to that goal of 355-sec. Once successful, the next step will be to develop the main engine technologies with a pre-prototype engine. This engine could be either ablative or regeneratively cooled.

The descent main engine activities have successfully demonstrated stable throttling to 10% thrust or less with multiple injector concepts using liquid oxygen and liquid hydrogen propellants. The Pratt&Whitney Rocketdyne CECE demonstrator engine test series concluded with 7,435.8 seconds (123.9 minutes) of total run time. The testing demonstrated chamber pressure and mixture ratio closed-loop control over a wide range of throttled power levels, fast throttle ramp rates, minimum power down to a smooth start to 10% power, eleven rapid relights demonstrated, and high power, high mixture ratio operation. The testing also demonstrated low power stability, including chug-free operation down to 5.9% power. This represents a 17.6:1 overall cryogenic deep throttling ratio in a complete expander cycle engine system with all system-level interactions which greatly enhanced the value of the technology database acquired. Testing with a pintle injector from Northrop Grumman was successful in meeting all primary and secondary technical objectives including high performance (>98% C* (combustion) efficiency); stable 10:1 deep throttling; measurement of heat transfer characteristics; evaluation of off-nominal oxidizer to fuel mixture ratio (MR) sensitivities; and evaluation of L* sensitivity. Finally, a NASA in-house developed dual oxygen manifold injector was also able to demonstrate stable throttling to a 10% power level.

The PCAD team continues to build upon the success to date and strives to provide timely and relevant data to NASA mission study teams so an informed decision can be made on the direction of the next propulsion system for exploration missions.

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The authors gratefully acknowledge the leadership afforded this project from the ETDP program; Frank Peri, Program Manager; Richie Law, Integration Manager; and Diane Hope, Program Element Manager. The authors also want to acknowledge the center teams; from NASA GRC Todd Peterson,

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Appendix I. Propulsion & Cryogenic Advanced Development Project

Propulsion & Cryogenics Advanced Development Project

Transition Review with ETDP

July 20, 2010

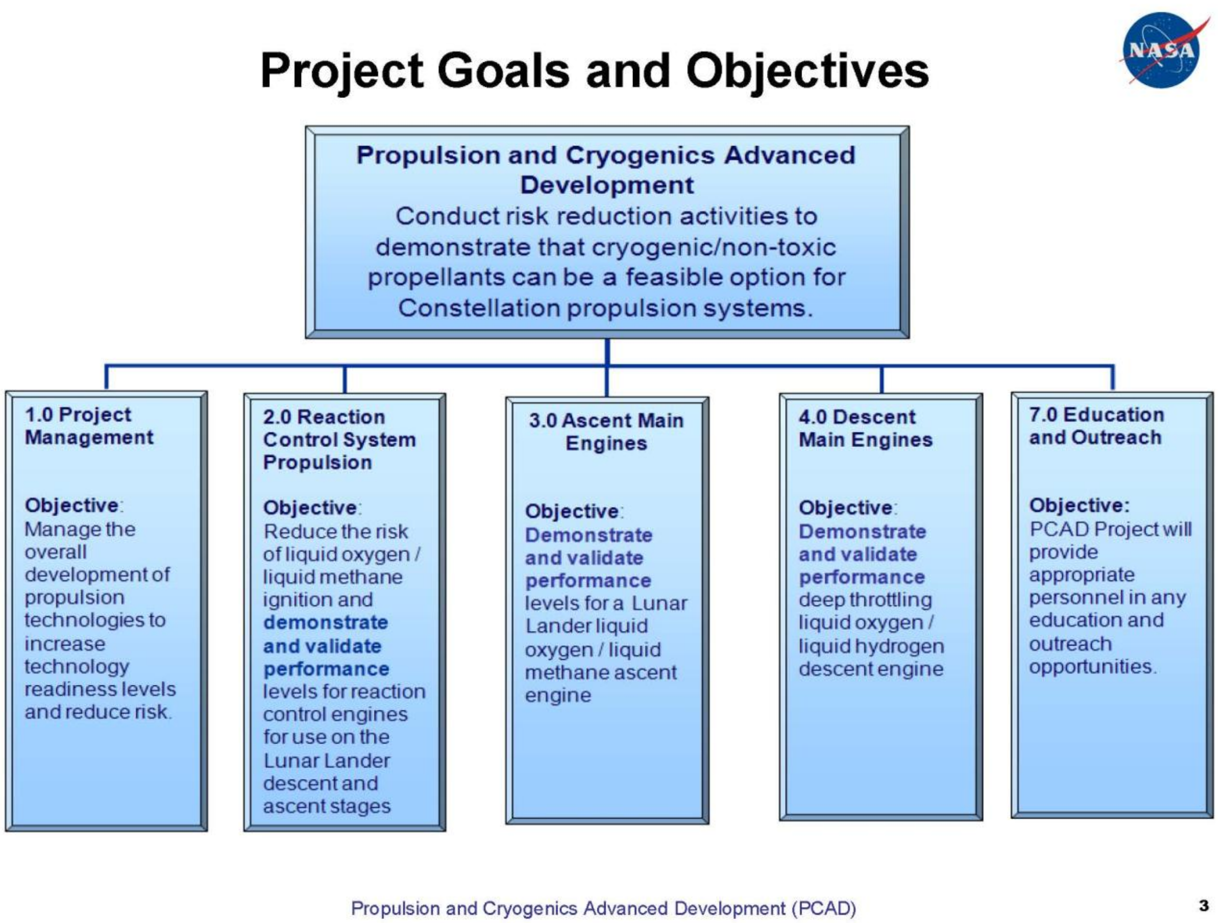
Mark Klem
Tim Smith
Ken Fisher
Lori Aponte-Richter
Marilyn Groff

Propulsion and Cryogenics Advanced Development (PCAD) 1

Outline

- Project Goals and Objectives
- Risk Areas
- FY10 Year to Date
- Milestones and Deliverables
- Accomplishments over the years
- KPP and TRL Summary
- Risks
- Transition Activities
  - Archives
  - Publications and Outreach
  - Lessons Learned
- Back-up
  - Accomplishment Slides
  - Bibliography

Propulsion and Cryogenics Advanced Development (PCAD) 2


Project Goals and Objectives
Propulsion and Cryogenics Advanced Development
Conduct risk reduction activities to demonstrate that cryogenic/non-toxic propellants can be a feasible option for Constellation propulsion systems.
1.0 Project Management
Objective: Manage the overall development of propulsion technologies to increase technology readiness levels and reduce risk.
2.0 Reaction Control System Propulsion
Objective: Reduce the risk of liquid oxygen / liquid methane ignition and demonstrate and validate performance levels for reaction control engines for use on the Lunar Lander descent and ascent stages
3.0 Ascent Main Engines
Objective: Demonstrate and validate performance levels for a Lunar Lander liquid oxygen / liquid methane ascent engine
4.0 Descent Main Engines
Objective: Demonstrate and validate performance deep throttling liquid oxygen / liquid hydrogen descent engine
7.0 Education and Outreach
Objective: PCAD Project will provide appropriate personnel in any education and outreach opportunities.
Propulsion and Cryogenics Advanced Development (PCAD)
3

Propulsion Risk Areas

- **Reaction Control Technology**
  - Reliable ignition
  - Performance
  - Repeatable pulse width
- **Ascent Main Engine**
  - Reliable ignition
  - Performance
  - Fast start
- **Descent Main Engine**
  - Stable throttling
  - Performance
  - Reliable ignition

Propulsion and Cryogenics Advanced Development (PCAD) 4

PCAD FY10 Year To Date

- Team has completed a number of significant milestones
  - Aerojet AME sea level and altitude testing
  - Aerojet 100-lbf altitude performance and Ibit testing
  - Pintle injector sea level testing
  - CECE Demo 1.7 altitude testing
- Project has absorbed $5.4M in budget cuts
- 22 PCAD papers presented at JANNAF Liquid Propulsion Meeting (May 2010)
- 1 International Paper
- 4 AIAA Papers (3 JPC, 1 Space2010)
- Work remaining in FY10
  - IPSTB CDR – August 24-25
  - Complete WASK transpiration chamber testing – July
  - Complete Aerojet Deep Throttling Injector Design - August

Propulsion and Cryogenics Advanced Development (PCAD) 5

FY10 Milestones and Deliverables

Propulsion and Cryogenics Advanced Development

Reportable Milestones

PCAD FY10 Key Milestones 2.0 Reaction Control Engine Technologies								
WBS	MS Number	Milestone Name	Baseline M/S Finish	Projected M/S Finish	Approx Budget ($K)	Status	Comments	Description
2.1	MS - PCAD 2.1-03	Variable Energy Exciter (VEE) Breadboard Demonstration Test	11/25/09	12/31/09	200	Complete		Complete altitude testing of a Variable Energy Exciter with a LOx/LCH4 igniter
2.1	MS - PCAD 2.1-12	Complete Heated Tube gas phase methane heat transfer testing	12/15/09	7/31/10	600	In-progress		Complete heated tube testing with *gaseous* methane to characterize heat transfer coefficients
2.1	MS - PCAD 2.1-10	Complete 100-lbf LOx/LCH_4 RCE altitude performance testing	1/31/10	2/15/10	1200	Complete		Vacuum performance testing over a range of propellant inlet conditions of a 100-lbf LOx/LCH_4 reaction control engine.
2.2	MS - PCAD 2.2-05	Integrated Propulsion System Test Bed (IPSTB) CDR	2/15/10	8/25/10	500	In-progress	Delays due to personnel availability	Complete critical design for integrated RCS and main engine LOx/LCH4 integrated rig
2.1	MS - PCAD 2.1-13	Unison Exciter Prototype LOx/LCH_4 hot-fire demonstration	4/30/10	5/11/10	250	Complete		LOx/LCH4 hot-fire demonstration of a prototype testing proof-of-concept (PoC) exciter design in an altitude environment with an 870-lbf igniter
2.1	MS - PCAD 2.1-16	Complete vacuum impulse bit testing of a 100-lbf LOx/LCH_4 reaction control engine	5/31/10	6/30/10	700	Complete		Vacuum testing over a range of propellant inlet conditions of a 100-lbf LOx/LCH_4 reaction control engine to determine pulse performance
2.1	MS - PCAD 2.1-17	Unison Exciter Design Assurance Test (DAT) hardware delivery	6/30/10	8/31/10	1000	In-progress	Delays continue at Unison due to delivery of materials and personnel availability. Aerojet has initiated daily phone meeting with the Unison lead to pull back schedule and avoid any further delays.	Delivery of prototype testing proof-of-concept (PoC) exciters with modifications from first units
2.1	MS - PCAD 2.1-18	Complete vacuum ignition margin testing of a 100-lbf LOx/LCH_4 reaction control engine	6/30/10	FY11 - TBD	700	Delay - Budget Cut	Testing cannot continue until FY11. Due to project direction and budget uncertainty, no date can be set for completion.	Vacuum testing over a range of propellant inlet conditions of a 100-lbf LOx/LCH_4 reaction control engine to determine where the engine will light and not light
2.1	MS - PCAD 2.1-15	Complete fabrication of modified NGAS 100-lbf LOx/LCH_4 reaction control engines	7/31/10		500	Cancelled - Budget Cut	Due to May budget cut, this work will not be completed. Contract 5 year period of performance will expire before funds could become available in FY11	Complete fabrication of modified NGAS regen cooled 100-lbf LOx/LCH_4 reaction control engines. Engines will be modified to improve heat transfer in combustion chamber.
2.2	MS - PCAD 2.2-06	Integrated Propulsion System Test Bed (IPSTB) Structure Complete	9/30/10	FY11 - TBD	1500	Delay - Budget Cut	Delayed 9 months to 1 year based on budget cuts announced Jan 25, 2010. Funding reduced by $875K in procurement. Funding only available to work design in FY10. All long lead and other purchases on-hold	Complete fabrication and layout of the IPSTB support structure.

CSA/L1 Milestone
CSA Milestone

Propulsion and Cryogenics Advanced Development (PCAD) 7

Propulsion and Cryogenics Advanced Development

Reportable Milestones

PCAD FY10 Key Milestones
3.0 Ascent Main Engine Technologies

WBS	MS Number	Milestone Name	Baseline M/S Finish	Projected M/S Finish	Approx Budget	Status	Comments	Description
3.1	MS - PCAD 3.1-04	Aerojet AME workhorse engine sea level engine for altitude test - unit 1 delivery	1/31/10	2/28/10	500	Complete		Complete sea level performance (C*) and high frequency stability pulse gun testing at Aerojet of a 5,500-lbf LOx/LCH4 Ascent Main Engine (AME) workhorse engine - deliver injector, chamber and valves
3.1	MS - PCAD 3.1-03	Aerojet AME workhorse engine sea level test complete **(APG 10AC16)**	2/26/10	3/31/10	3500	Complete		Complete sea level performance (C*) and high frequency stability pulse gun testing at Aerojet of a 5,500-lbf LOx/LCH4 Ascent Main Engine (AME) workhorse engine.
3.2	MS - PCAD 3.2-06	CFD modeling of reacting unsteady flow with supercritical propellants in a shear coaxial injector	3/31/10	7/31/10	100	In-progress	Personnel availability: the contractor (Jacobs) was delayed in making an offer due to implications of the budget rollout in Feb. Contractor did not want to bring on new staff. Contract hired will only be employed through May. Currently working to find new staff at MSFC or new contractor to complete work.	Complete CFD analysis of a shear coaxial injector with supercritical hydrogen, methane, and oxygen propellants. Comparison of heat flux predictions with test data to get within 20% accuracy between data and predictions.
3.2	MS - PCAD 3.2-07	CFD modeling of reacting steady flow with supercritical propellants in a swirl coaxial injector	3/31/10		100	Cancelled - Technical reasons - EDTP Approval 5/11/2010	Work showed that the steady simulation of a swirling jet compared so poorly to the data (and the unsteady simulation) that is was essentially useless. Objectives are better served focusing on the unsteady cold flow and unsteady reacting simulations.	Complete CFD analysis of a swirl coaxial injector with supercritical hydrogen, methane, and oxygen propellants. Comparison of heat flux predictions with test data to get within 20% accuracy between data and predictions.
3.11	MS - PCAD 3.11-01	LOx/Methane Transpiration Cooled Chamber Fabrication	3/31/10	6/30/10	200	Complete		Complete fabrication of a 6000-lbf LOx/Methane transpiration cooled combustion chamber for sea level testing
3.6	MS - PCAD 3.6-01	Complete sea level testing of uncooled chambers with HfO2/Ir liners	3/31/10	FY11 - TBD	250	Delay - Technical	Delay due to fabrication problems with 1000-lbf chamber - chamber will not be delivered until December 2010. The 6000-lbf chamber testing was started. However chamber developed leaks at seal with the injector after 2 3-sec runs. Test team currently evaluating options.	Fabrication and testing of uncooled combustion chambers with HfO2/Ir liners and Carbon-Carbon chambers. Chambers are being delivered as part of an IPP and a Phase II SBIR
3.1	MS - PCAD 3.1-06	Aerojet LOx/LCH_4 Ascent Main Engine (AME) workhorse engine altitude testing	4/30/10	3/31/10	1600	Complete		Complete altitude performance testing at WSTF TS401 of a 5,500-lbf LOx/LCH4 Ascent Main Engine (AME) workhorse engine to deterimine specific impulse, altitude ignition and ablative chamber life.
3.9	MS - PCAD 3.9-01	Sea Level hot-fire testing of PWR LCH_4 regen cooled combustion chambers	5/15/10	FY11 - TBD	240	Delay - Technical	Injector was severely damaged on 7th test of program and cannot be repaired. Testing cannot continue until FY11. Due to project direction and budget uncertainty, no date can be set for completion.	Complete Sea Level hot-fire testing of PWR LCH4 regen cooled combustion chambers to determine heat transfer effectiveness of coolant channel designs
3.11	MS - PCAD 3.11-02	LOx/Methane Transpiration Cooled Chamber Sea Level Testing Complete	6/30/10	7/31/10	400	In-progress	Hardware design activities complete and fabrication in process	Complete sea level testing of a 6000-lbf LOx/Methane transpiration cooled combustion chamber at NASA MSFC
3.9	MS - PCAD 3.9-02	Heated tube two phase methane heat transfer characterization	6/30/10	1/31/10	100	Complete		Complete heated tube testing with liquid methane to characterize two-phase heat transfer coefficients
3.10	MS - PCAD 3.10-01	Preliminary design review of long duration exposure valve	9/30/10		200	Cancelled - Budget Cut	Due to May budget cut, this work will not be completed.	Preliminary design review of a cryogenic valve for use in long duration exposure testing.
3.2	MS - PCAD 3.2-08	CFD modeling of reacting unsteady steady flow with supercritical propellants in a swirl coaxial injector	9/30/10		100			Complete CFD analysis of a swirl coaxial injector with supercritical hydrogen, methane, and oxygen propellants. Comparison of heat flux predictions with test data to get within 20% accuracy between data and predictions.

CSA/L1 Milestone
CSA Milestone

Propulsion and Cryogenics Advanced Development (PCAD) 8

Propulsion and Cryogenics Advanced Development

Reportable Milestones

PCAD FY10 Key Milestones
4.0 Descent Main Engine Technologies

WBS	MS Number	Milestone Name	Baseline M/S Finish	Projected M/S Finish	Approx Budget ($K)	Status	Comments	Description
4.2	MS - PCAD 4.2-02	Pintle Injector Test Series 2 - Calorimeter Complete	12/31/09	11/20/09	500	Complete		Demonstrate stable throttling from 100% to 10% power, ignition characteristics, and quantify combustion performance (C*) at variable power levels a LOx/LH2 of a pintle injector and obtain critical heat flux data
4.4	MS - PCAD 4.4-01	Complete LOx/LH_2 Two Stage injector testing	12/31/09	3/4/10	300	Complete		Demonstrate stable throttling from 100% to 10% power, ignition characteristics, and quantify combustion performance (C*) at variable power levels a LOx/LH2 throttling two stage injector
4.3	MS - PCAD 4.3-02	Advanced Turbine Bypass Valve Test	1/31/10	4/7/10	200	Complete	Delays in transitioning key personnel until start of FY10 pushed out test schedule. Test readiness review completed.	Complete sea level testing of a Advanced Turbine Bypass Valve Test
4.6	MS - PCAD 4.6-01	Throttling Valve and Control System (TVCS) Technology Development Requirements Document	2/28/10	4/30/10	250	Complete	Team presented plans to PCAD on April 28	Develop plans to address throttling valve technologies: 1) flow element design, 2) Actuator accuracy and precision, 3) feedback measurement, 4) controller logic and power, and 5) space hardening
4.1	MS - PCAD 4.1-06	PWR CECE Demo 1.7 testing	4/30/10	4/17/10	5000	Complete	Test planning activities continuing. On track for March 3 engine installation in E6 test facility. Test readiness review scheduled for March 9	Altitude testing with an insulated injector to examine throttling control tolerances, throttle ramp rates, minimum power start, closed loop control and reliable chug free operation between 100% and 10% power.
4.2	MS - PCAD 4.2-03	TR202 Throttling Actuator Critical Design Review	6/30/10	8/31/10	500	In-progress		Complete to CDR level the actuator mechanism to allow continuous throttle between 100% to 10% power of the NGAS pintle injector during hot fire testing.
4.5	MS - PCAD 4.5-01	LLDETB Regen Combustion Chamber Hot-Fire Checkout Test	6/30/10	10/31/10	500	In-progress	Test stand not available until September 2010 due to Constellation projects	Complete sea level testing of a LH2 cooled regen combustion chamber. Quantify heat transfer characteristics at power levels of 100% to 5%.
4.4	MS - PCAD 4.4-02	Complete Aerojet Descent Throttling Injector (DTI) design	8/15/10		700	In-progress	Date finalized based on Aerojet Baseline Schedule.	Complete detailed design review (DDR) of a dual LOx orifice throttling LOx/LH2 descent engine rocket injector. Injector will be designed for stable performance from 100% to 10% power.

CSA/L1 Milestone
CSA Milestone

Propulsion and Cryogenics Advanced Development (PCAD) 9

Propulsion and Cryogenics Advanced Development

Reportable Milestones

2.0 Reaction Control Engine Technologies							
WBS	Deliverable Name	Baseline	Projected	Status	Product	Comments
DEL - PCAD 2.1-08	Aerojet 100-lbf LOx/LCH4 RCE Contract Final Report	12/31/09	07/31/10	In-progress	Report	Delayed due to personnel availability. (supporting AME and new DTI activities)
DEL - PCAD 2.1-05	NDE method and failure model for spark plug ceramics report	12/31/09	03/31/10	Complete	Report	
DEL - PCAD 2.1-03	Variable Energy Exciter (VEE) Breadboard Demonstration Test Report	01/29/10	06/30/10	In-progress	Report	Testing completed Dec 09
DEL - PCAD 2.2-02	WSTF 100-lbf LOx/LCH4 RCE Integrated Testing Report	01/29/10	08/31/10	In-progress	Report	Delayed due to personnel availability. (supporting IPSTB design)
DEL - PCAD 2.2-05	Integrated Propulsion System Test Bed (IPSTB) CDR	02/15/10	07/15/10	Delay	Presentation	Delayed
DEL - PCAD 2.1-12	Complete Heated Tube gas phase methane heat transfer testing	02/28/10	09/30/10	Delay	Report	Switched test dates with MS 3.9-02
DEL - PCAD 2.1-10	Complete 100-lbf LOx/LCH_4 RCE altitude performance testing	05/31/10		Complete	Report	JANNAF Report
DEL - PCAD 2.1-17	Unison Exciter Design Assurance Test (DAT) hardware delivery	06/30/10	09/30/10	In-progress	Hardware	
DEL - PCAD 2.1-16	Complete 100-lbf LOx/LCH_4 RCE impulse bit testing	07/30/10		In-progress	Report	
DEL - PCAD 2.1-13	Unison Exciter Prototype LOx/LCH_4 hot-fire demonstration	07/31/10		In-progress	Report	
DEL - PCAD 2.1-15	Complete fabrication of modified NGAS 100-lbf LOx/LCH_4 reaction control engines - Delivery	07/31/10		Cancelled - Budget	Hardware	Due to May budget cut, this work will not be completed. Contract 5 year period of performance will expire before funds could become available in FY11
DEL - PCAD 2.1-09	Northrop Grumman 100-lbf LOx/LCH4 RCE Contract Final Report	09/30/10	06/30/10	In-progress	Report	
DEL - PCAD 2.2-06	Integrated Propulsion System Test Bed (IPSTB) Structure Complete	09/30/10	FY11 - TBD	Delay	Hardware	Budget Cut
DEL - PCAD 2.1-18	Complete vacuum ignition margin testing of a 100-lbf LOx/LCH_4 reaction control engine	09/30/10	FY11 - TBD	Delay	Report	Budget Cut

Propulsion and Cryogenics Advanced Development

Reportable Milestones

WBS	Deliverable Name	Baseline	Projected	Status	Product	Comments
3.0 Ascent Main Engine Technologies						
DEL - PCAD 3.1-04	Aerojet AME workhorse engine sea level engine for altitude test - unit 1 delivery	01/30/10	02/28/10	Complete	Hardware	Fabrication complete of 3 injectors. Injectors 2 and 3 did not perform well and will not be tested at altitude testing. Only injector 1 will have limited altitude testing.
DEL - PCAD 3.2-06	CFD modeling of reacting unsteady flow with supercritical propellants in a shear coaxial injector	03/31/10	09/15/10	In-progress	Report	Personnel availability
DEL - PCAD 3.2-07	CFD modeling of reacting steady flow with supercritical propellants in a swirl coaxial injector	03/31/10		Cancelled - Technical	Report	See MS description
DEL - PCAD 3.11-0	LOx/Methane Transpiration Cooled Chamber Fabrication	04/15/10	06/30/10	In-progress	Hardware	
DEL - PCAD 3.1-03	Aerojet AME contract final report	04/30/10	07/31/10	In-progress	Report	Additional scope added to contract
DEL - PCAD 3.6-01	Complete sea level testing of uncooled chambers with HfO2/Ir liners	05/31/10	TBD	In-progress	Report	Hardware failed on test stand. Repairs TBD
DEL - PCAD 3.9-01	Sea Level hot-fire testing of PWR LCH_4 regen cooled combustion chambers	07/31/10	TBD	In-progress	Report	Hardware failed on test stand. Repairs TBD
DEL - PCAD 3.1-06	Aerojet LOx/LCH_4 Ascent Main Engine (AME) workhorse engine altitude testing	08/30/10	04/30/10	Complete	Report	JANNAF Report
DEL - PCAD 3.11-0	LOx/Methane Transpiration Cooled Chamber Sea Level Testing Complete	09/30/10		In-progress	Report	
DEL - PCAD 3.9-02	Heated tube two phase methane heat transfer characterization	09/30/10	04/30/10	Complete	Report	JANNAF Report
DEL - PCAD 3.10-0	Preliminary design review of long duration exposure valve	09/30/10		Cancelled - Budget	Presentation	RFP will not be released due to budget cuts
DEL - PCAD 3.2-08	CFD modeling of reacting unsteady steady flow with supercritical propellants in a swirl coaxial injector	09/30/10			Report	
4.0 Descent Main Engine Technologies						
WBS	**Deliverable Name**	**Baseline**	**Projected**	**Status**	**Product**	**Comments**
DEL - PCAD 4.2-02	Pintle Injector Test Series 2-Calorimeter Complete	01/31/10	02/28/10	Complete	Report	Report complete and submitted by NGAS, in final review at NASA
DEL - PCAD 4.6-01	Throttling Valve and Control System (TVCS) Technology Development Requirements Document	02/28/10	04/30/10	Complete	Report	Presentation to PCAD - April 28
DEL - PCAD 4.4-01	Complete LOx/LH_2 Two Stage injector testing	03/15/10	04/30/10	Complete	Report	JANNAF Report
DEL - PCAD 4.3-02	Advanced Turbine Bypass Valve Test	03/31/10	07/31/10	In-progress	Report	Testing completed
DEL - PCAD 4.2-03	TR202 Throttling Actuator Critical Design Review	06/30/10	08/31/10	In-progress	Presentation	
DEL - PCAD 4.1-06	PWR CECE Demo 1.7 testing	07/30/10		In-progress	Report	Testing Complete
DEL - PCAD 4.5-01	LLDETB Regen Combustion Chamber Hot-Fire Checkout Test	08/31/10	11/30/10	Delay	Report	Test stand not available until September 2010 due to Constellation projects
DEL - PCAD 4.4-02	Complete Aerojet Descent Throttling Injector (DTI) design	8/15/10		In-progress	Presentation	Date finalized based on Aerojet Baseline Schedule.

Propulsion and Cryogenics Advanced Development (PCAD) 11

What did not or will not get done from FY10?

- **Completion of full RCS testing at ACS**
  - Complete ignition margin test
  - Complete altitude thermal (hot and cold) environment testing of RCS engine
  - Complete prototype regen cooled RCS engine
- **Integrated Propulsion System Test Bed**
  - Fabrication of IPSTB
- **Ascent Main Engine**
  - Sea level testing of Injector 1 – Rev 3
  - Long Duration Cryogenic valve technology RFP and contracts
- **Descent Main Engine**
  - Design of throttling engine test bed (any current work under MSFC IRAD)

Propulsion and Cryogenics Advanced Development (PCAD) 12

What was planned for FY11?

- **Completion of full RCS testing at ACS**
  - Complete altitude testing of regen cooled altitude testing
- **Integrated Propulsion System Test Bed**
  - Fabrication of IPSTB
- **Ascent Main Engine**
  - Heated tube two-phase flow instability characterization/mapping
  - Single element and subscale LOx/LCH_4 injector fabrication and characterization
  - Fabrication and sea level testing of 60-element LOx/LCH_4 injector.
  - Subcritical CFD modeling of shear and swirl coaxial elements.
  - Fabrication and testing of long duration cryogenic valve technologies
  - Altitude testing of transpiration cooled chamber
- **Descent Main Engine**
  - Build-up and testing of multiple injectors and chambers in throttling engine test bed
  - Development of throttling valve and control technologies

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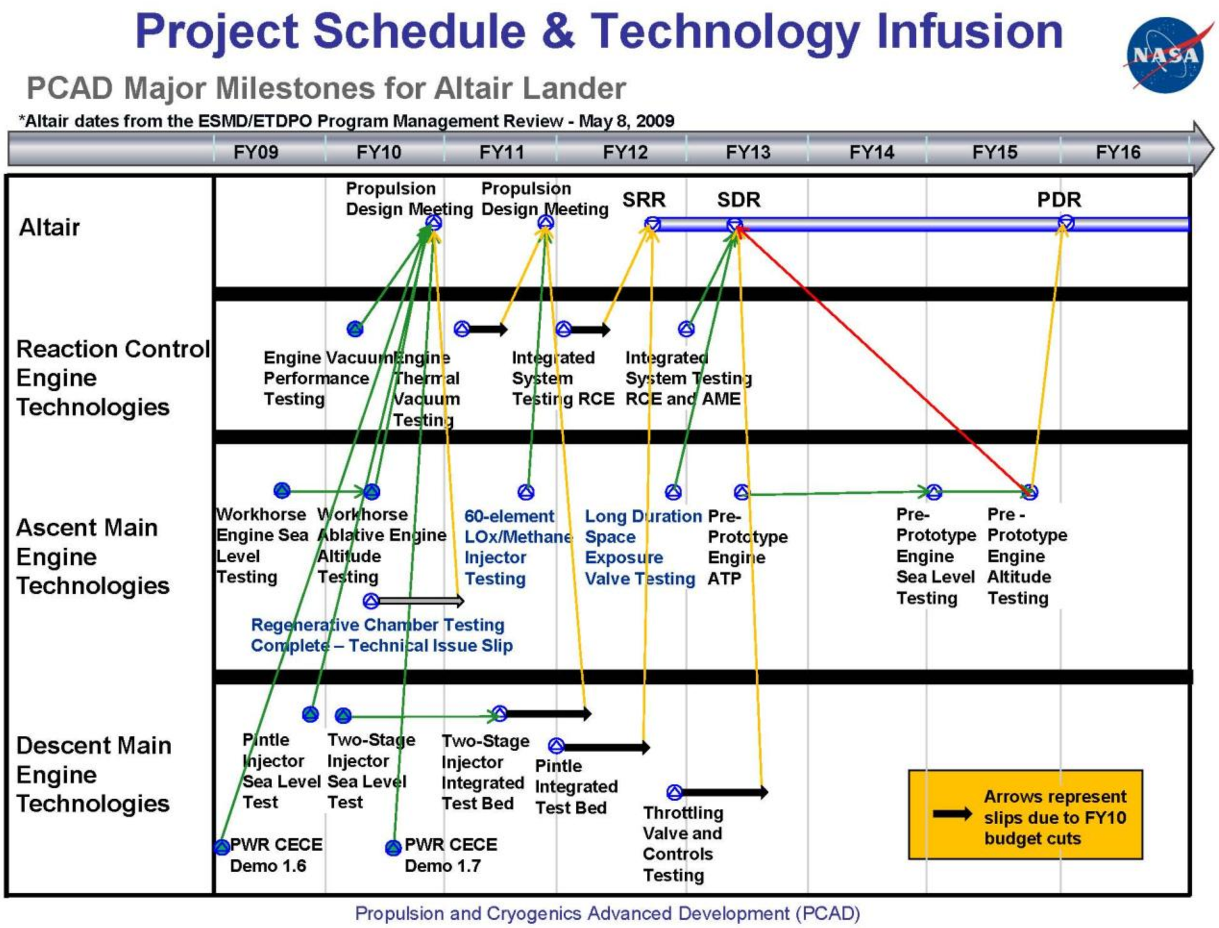
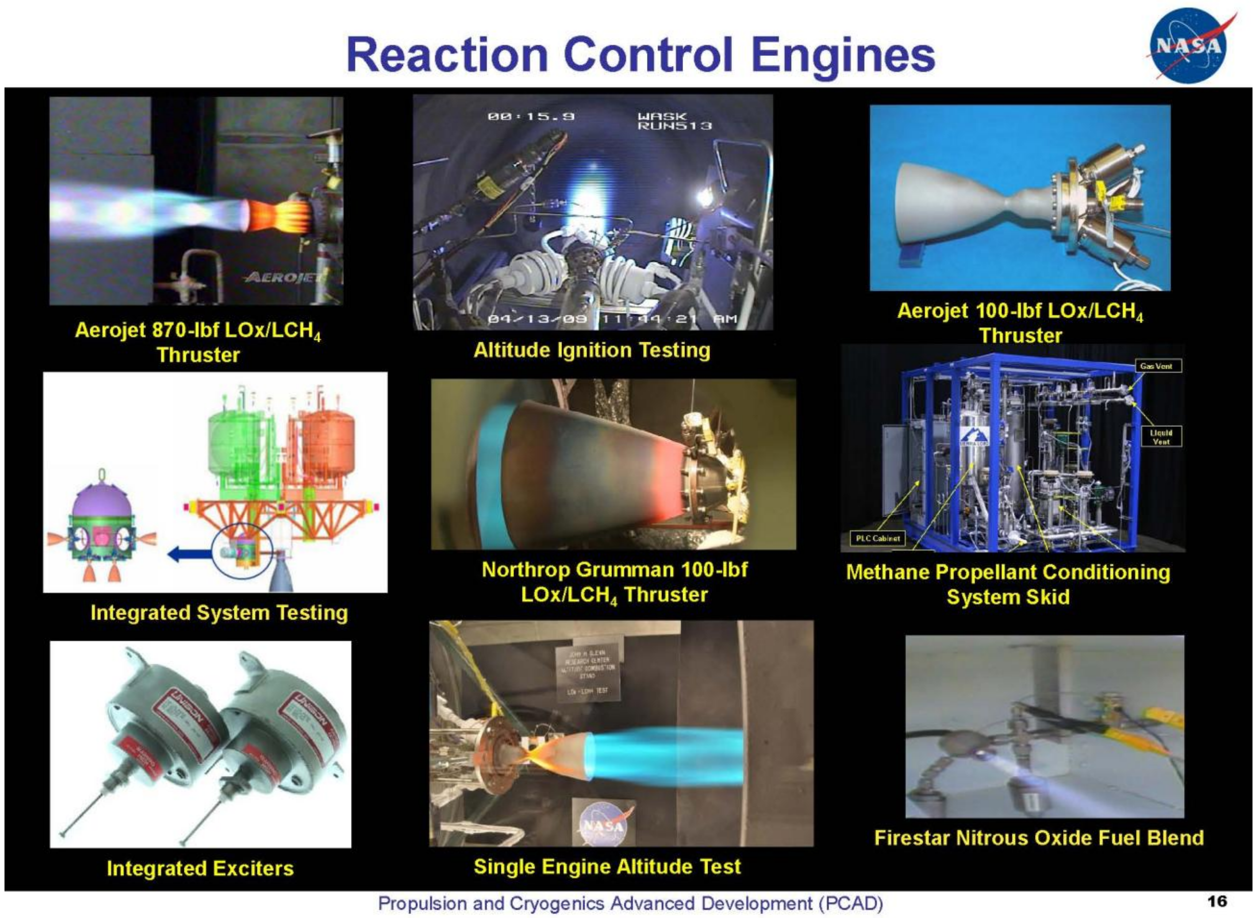

Project Schedule & Technology Infusion
PCAD Major Milestones for Altair Lander
*Altair dates from the ESMD/ETDPO Program Management Review - May 8, 2009
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
Altair
Propulsion Design Meeting
Propulsion Design Meeting
SRR
SDR
PDR
Reaction Control Engine Technologies
Engine Vacuum Performance Testing
Engine Thermal Vacuum Testing
Integrated System Testing RCE
Integrated System Testing RCE and AME
Ascent Main Engine Technologies
Workhorse Engine Sea Level Testing
Workhorse Ablative Engine Altitude Testing
60-element LOx/Methane Injector Testing
Long Duration Space Exposure Valve Testing
Pre-Prototype Engine ATP
Pre-Prototype Engine Sea Level Testing
Pre - Prototype Engine Altitude Testing
Regenerative Chamber Testing Complete – Technical Issue Slip
Descent Main Engine Technologies
Pintle Injector Sea Level Test
Two-Stage Injector Sea Level Test
Two-Stage Injector Integrated Test Bed
Pintle Integrated Test Bed
Throttling Valve and Controls Testing
PWR CECE Demo 1.6
PWR CECE Demo 1.7
Arrows represent slips due to FY10 budget cuts
Propulsion and Cryogenics Advanced Development (PCAD)

Accomplishments
PCAD Over the Years


Reaction Control Engines
Aerojet 870-lbf LOx/LCH4 Thruster
Altitude Ignition Testing
Aerojet 100-lbf LOx/LCH4 Thruster
Integrated System Testing
Northrop Grumman 100-lbf LOx/LCH4 Thruster
Methane Propellant Conditioning System Skid
Integrated Exciters
Single Engine Altitude Test
Firestar Nitrous Oxide Fuel Blend
Propulsion and Cryogenics Advanced Development (PCAD)
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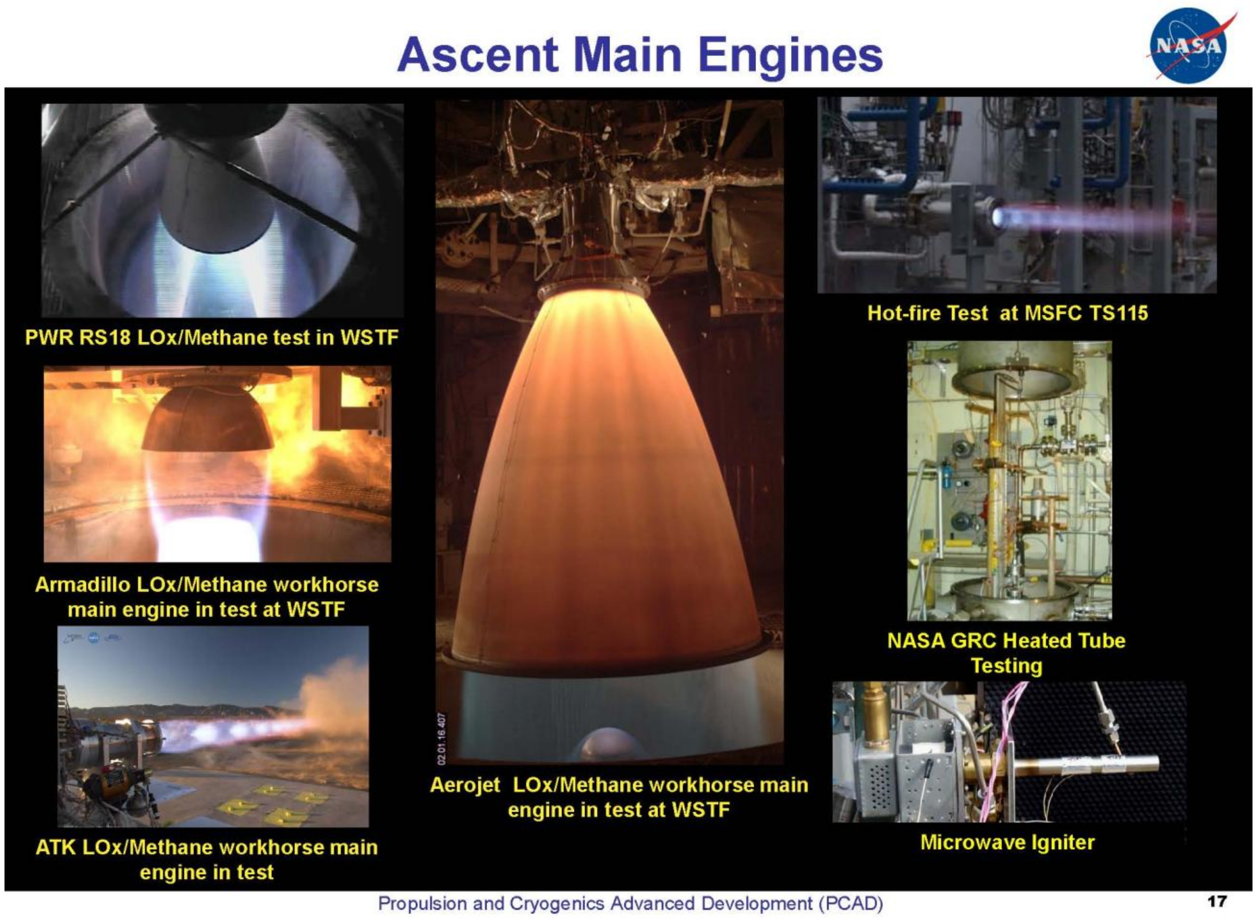
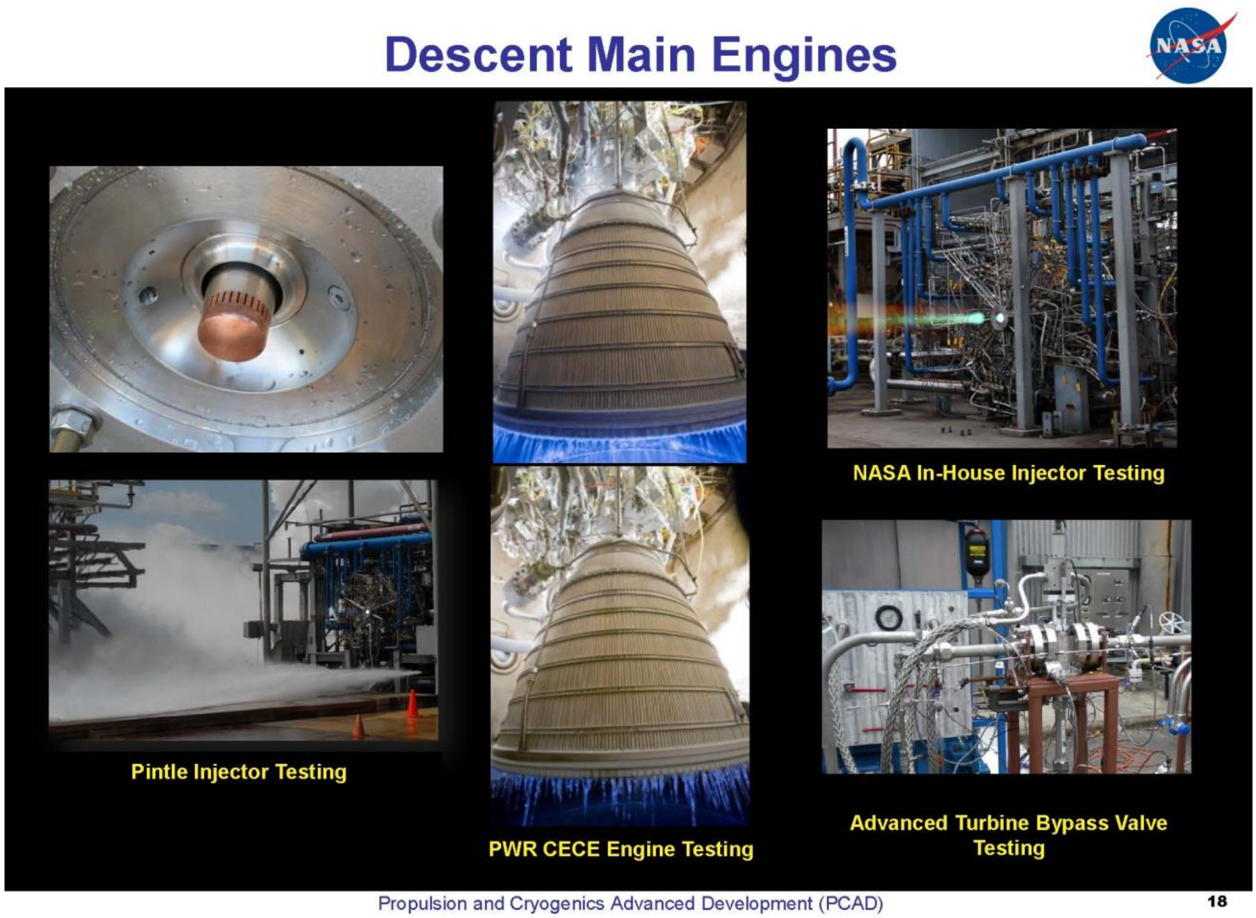

Ascent Main Engines
PWR RS18 LOx/Methane test in WSTF
Armadillo LOx/Methane workhorse main engine in test at WSTF
ATK LOx/Methane workhorse main engine in test
Aerojet LOx/Methane workhorse main engine in test at WSTF
Hot-fire Test at MSFC TS115
NASA GRC Heated Tube Testing
Microwave Igniter
Propulsion and Cryogenics Advanced Development (PCAD)
17



Descent Main Engines
NASA In-House Injector Testing
Pintle Injector Testing
PWR CECE Engine Testing
Advanced Turbine Bypass Valve Testing
Propulsion and Cryogenics Advanced Development (PCAD)
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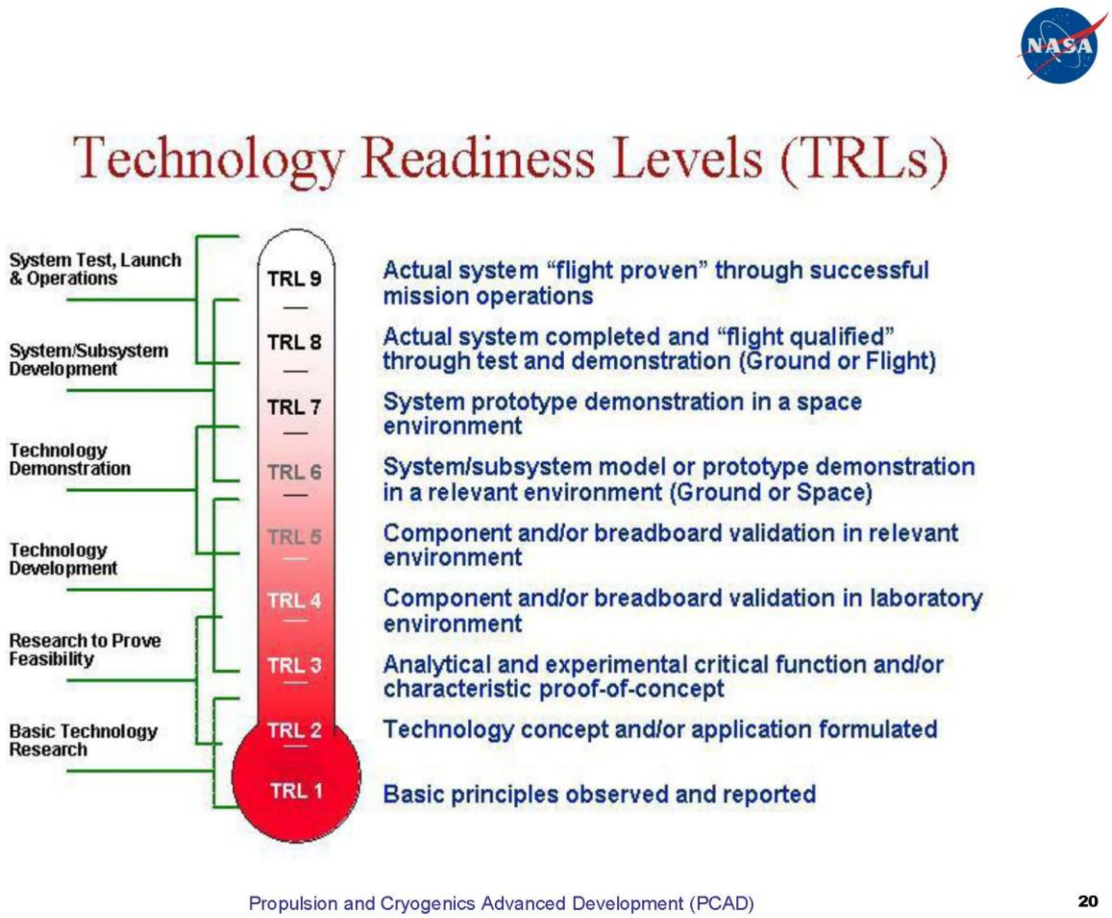
Progress Against KPPs and TRL assessment

Propulsion and Cryogenics Advanced Development (PCAD) 19


Technology Readiness Levels (TRLs)
System Test, Launch & Operations
System/Subsystem Development
Technology Demonstration
Technology Development
Research to Prove Feasibility
Basic Technology Research
TRL 9
TRL 8
TRL 7
TRL 6
TRL 5
TRL 4
TRL 3
TRL 2
TRL 1
Actual system "flight proven" through successful mission operations
Actual system completed and "flight qualified" through test and demonstration (Ground or Flight)
System prototype demonstration in a space environment
System/subsystem model or prototype demonstration in a relevant environment (Ground or Space)
Component and/or breadboard validation in relevant environment
Component and/or breadboard validation in laboratory environment
Analytical and experimental critical function and/or characteristic proof-of-concept
Technology concept and/or application formulated
Basic principles observed and reported
Propulsion and Cryogenics Advanced Development (PCAD)
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TRL from 7120.8

TRL 5 - Component and/or breadboard validation in relevant environment.

- **Hardware:** A ***medium*** fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases

TRL 6 - System/sub-system model or prototype demonstration in an operational environment..

- **Hardware:** A ***high*** fidelity system/component prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.

Reaction Control Engines

Customer Requirements/Needs	Key Performance Parameters	Threshold Value	Progress
Develop 100-lb_f LOx/LCH_4 reaction control engine and integrated feedsystem to TRL 5-6 level.	a. Thrust b. Specific Impulse c. Minimum Impulse Bit d. Propellant quality delivered to the engine	a. Minimum thrust of 100 lbf (vacuum), over engine life. b. Minimum specific impulse of 317 seconds (vacuum) at the end of life. c. Minimum of 4-lbf-sec d. Reliable repeatable pulses with subcooled liquids in main feedline and no more than 1/3 cu inches of gas at the engine valve	a. Both Aerojet and Northrop Grumman reaction control engines demonstrated 100-lbf thrust during altitude testing. b. Aerojet engine demonstrated 317-sec Isp by analysis for an 80:1 area ratio nozzle. Altitude testing at an area ratio of 45:1 achieved 305-sec (extrapolates to 317-sec for 80:1) Northrop Grumman engine demonstrated 320-330-sec Isp during testing with the as planned 120:1 nozzle. c. Aerojet engine demonstrated a minimum impulse bit of 4-lbf-sec during sea level testing and altitude testing. d. Aerojet engine demonstrated 10 pulses with subcooled liquids at the engine valve during altitude testing. (50+ pulses at all temperatures)

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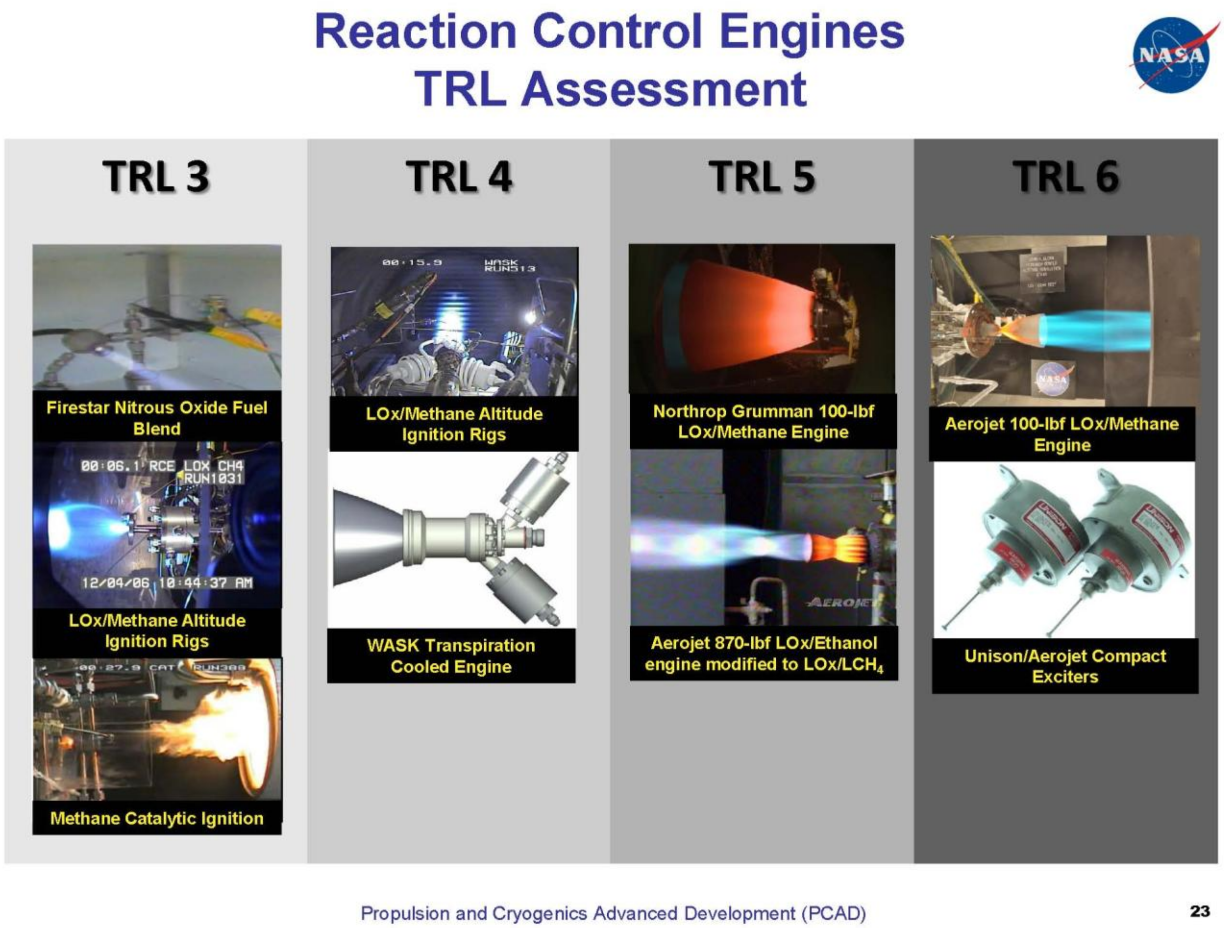
Reaction Control Engines
TRL Assessment
TRL 3
TRL 4
TRL 5
TRL 6
Firestar Nitrous Oxide Fuel Blend
LOx/Methane Altitude Ignition Rigs
Methane Catalytic Ignition
LOx/Methane Altitude Ignition Rigs
WASK Transpiration Cooled Engine
Northrop Grumman 100-lbf LOx/Methane Engine
Aerojet 870-lbf LOx/Ethanol engine modified to LOx/LCH4
Aerojet 100-lbf LOx/Methane Engine
Unison/Aerojet Compact Exciters
Propulsion and Cryogenics Advanced Development (PCAD)
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Reaction Control Engines TRL Assessment

PCAD Assessment: TRL 6

Aerojet engine achieved a TRL 6

- Engine tested was a high fidelity prototype

Northrop Grumman engine achieved a TRL 5.

- Engine tested was a medium fidelity brassboard.

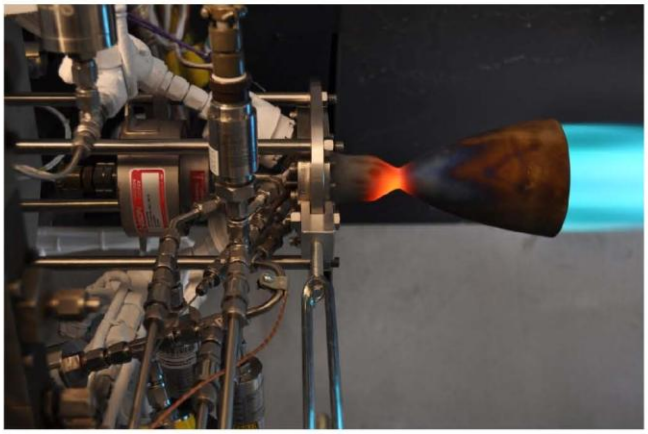
Propulsion and Cryogenics Advanced Development (PCAD) 24

Compact Exciters
TRL Assessment

PCAD Assessment: TRL 6

Unison exciter achieved a TRL 6

- Compact exciter tested at altitude in 870-lbf LOx/LCH_4 igniter rig.
- Compact exciter tested at altitude in 100-lbf LOx/LCH_4 engine
- Design Assurance Unit undergoing space radiation and vibration testing.



Propulsion and Cryogenics Advanced Development (PCAD)

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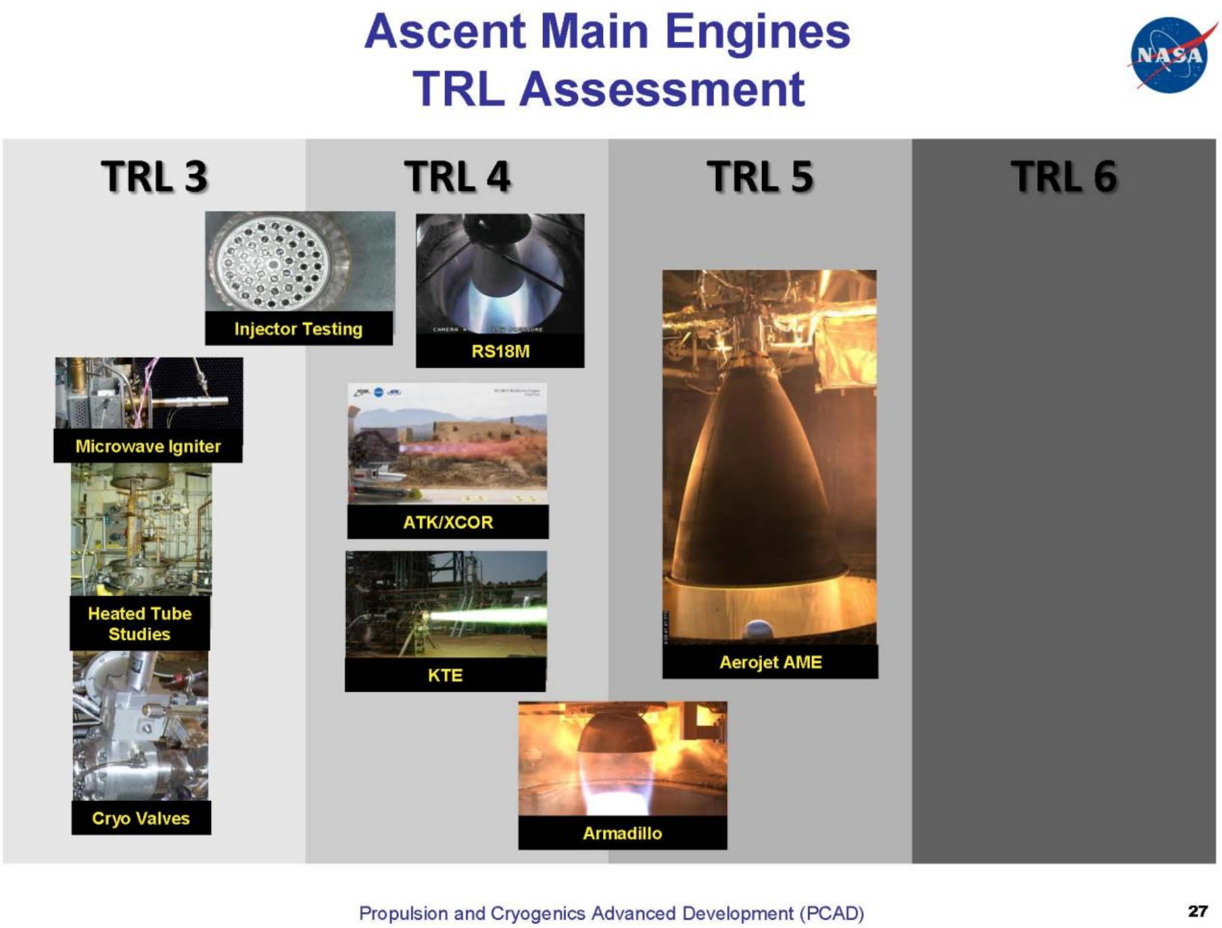
Ascent Main Engines

Customer Requirements/Needs	Key Performance Parameters	Threshold Value	Progress
Develop a LOx/LCH$_4$ in-space main engine demonstrators to TRL 5-6 level.	a. Specific Impulse b. Ignition Transient c. Restart d. Continuous single burn time. e. Total burn time.	a. Minimum specific impulse of 355 seconds (vacuum) at the end of life. b. The engine shall achieve 90% rated thrust within 0.5 second of the issuance of the Engine ON Command. c. 2 vacuum starts d. >600 continuous seconds of operation. e. >1425 total seconds of operation.	a. Aerojet engine demonstrated 348-sec Isp by analysis from altitude testing. Altitude testing completed with 129:1 area ratio nozzle, design to meet metric is 150:1. b. Aerojet engine demonstrated 90% thrust within 0.5-sec during sea level testing. c. Aerojet engine completed 8 vacuum starts. d. Maximum continuous operation was 40-sec. e. Total operation for a single injector and combustion chamber was 187-sec.

Propulsion and Cryogenics Advanced Development (PCAD) 26


Ascent Main Engines
TRL Assessment
TRL 3
TRL 4
TRL 5
TRL 6
Injector Testing
RS18M
Microwave Igniter
ATK/XCOR
Heated Tube Studies
KTE
Cryo Valves
Aerojet AME
Armadillo
Propulsion and Cryogenics Advanced Development (PCAD)
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Ascent Main Engine
TRL Assessment

PCAD Assessment: TRL 5

Aerojet engine achieved a TRL 5
- Engine tested was a medium fidelity prototype
- Applies only to ablative designs

- Need for TRL 6
  - Ablative
    - Technical : Additional injector patterns fabricated and tested.
    - Schedule: 3 years
    - Budget: $8M, including test costs
  - Regen cooled
    - Technical: Both injectors and chambers fabricated and tested
    - Schedule: 5 years
    - Budget: $20M, including test costs.

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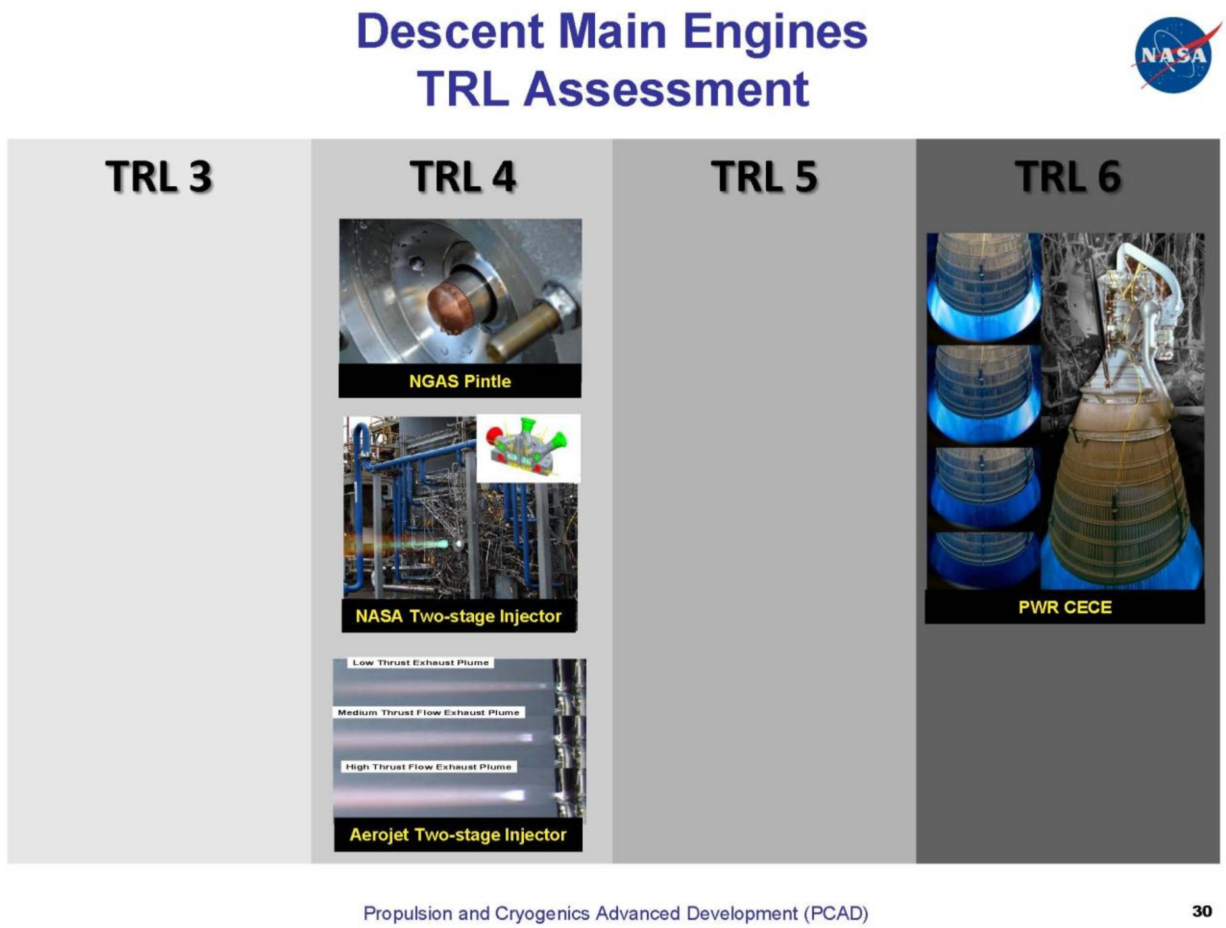
Descent Main Engines

Customer Requirements/Needs	Key Performance Parameters	Threshold Value	Progress
Demonstrate a 3:1 to 10:1 throttlable LOx/H_2 rocket engine technology for human rated propulsion applications.	a. Throttle Ratio b. Specific impulse af full power c. Specific impulse at minimum power d. Restartability e. Total burn time	a. Stable operation between 3:1(33% power) and 10:1 throttle (10% power) from engine full thrust (vacuum) b. Minimum specific impulse of 448 seconds (vacuum) - at 100% throttle c. Minimum specific impulse of 436 seconds (vacuum) - at min throttle setting d. 20 vacuum starts. e. >5000 seconds of operation.	a. Demonstrated stable operation over the range of 104% to 5.9% power, or a 17.6:1 throttling range during altitude testing with PWR CECE engine. b. Demonstrated 448-sec vacuum specific impulse at 100% power with PWR CECE engine c. Demonstrated 423-434-sec vacuum specific impulse at 10% power with PWR CECE engine over a mixture ratio range. d. Completed 20 vacuum ignition starts during PWR CECE Demo 1.7 testing. e. Total CECE Demo engine run time to-date is 7435.8 seconds (123.9 minutes).

Propulsion and Cryogenics Advanced Development (PCAD) 29



Descent Main Engines
TRL Assessment
TRL 3
TRL 4
TRL 5
TRL 6
NGAS Pintle
NASA Two-stage Injector
Low Thrust Exhaust Plume
Medium Thrust Flow Exhaust Plume
High Thrust Flow Exhaust Plume
Aerojet Two-stage Injector
PWR CECE
Propulsion and Cryogenics Advanced Development (PCAD)
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Descent Main Engine TRL Assessment

PCAD Assessment: TRL 6

PWR CECE achieved a TRL 6

- Engine tested was a high fidelity prototype
- Applies only to RL10 based design solution

- Other Concepts need for TRL 6
  - Pintle – current TRL 4
    - Technical : Dynamic throttling demonstration at the system level. No regen chamber or turbomachinery has been developed or tested. All testing has been injector component at sea level.
    - Schedule: 6 years
    - Budget: $40M, including test costs
  - Two Stage – current TRL 4
    - Technical : No testing with regen chamber or turbomachinery has been conducted. All testing has been injector component at sea level. Could be adapted to CECE
    - Schedule: 3 years
    - Budget: $40M, including test costs.

Propulsion and Cryogenics Advanced Development (PCAD) 31

Risks

PCAD Risk Assessment

Trend Since FY09 IBR	Risk ID and Open Date	Risk Title	Risk Statement (MUST USE - "Given that (state the fact)..there is a possibility (state the concern)... resulting in (state the consequence..)"	L	C	R	Affinity Group (Budget, Performance, Cost, Schedule)	Owner Initiator	Approach (M,W,A,R) Mitigate, Watch, Accept, Research	Status/Context	Mitigation WBS	Mitigation	Estimated Start Date Mitigation	Estimated End Date Mitigation
⇨	G-26	Methane Performance Analytical Models	Given that the main engine combustor designs are based on analytical models with limited input data due to global inexperience with LOx/CH_4 as a rocket propellant, the as-designed LOx/CH_4 Main Engine may not meet the End of Life ISP requirement of 355-sec	4	5	24	Performance	Mark Klem	M	Testing difficulties on both the regenerative and ablative concepts have yielded insufficent data to significantly reduce risk. Quality of the data and number of tests were not at levels the government team expected. Performance numbers are lower than desired to meet KPP from contractor activities. In-house work has shown promise but is limited to component level. AME contract with Aerojet is closing unless additional funds are made available.	2.2.2, 3.1.3, 3.2.4, 3.8, 3.9.1, 3.9.2, 3.9.3, 3.9.4, 3.10.1, 3.11	Continue work per existing 5.5K LOx/CH_4 Main Engine work, which will test ablative and and regeneratively-cooled chambers, both of which have their own effeciency challenges. Plan for follow-on work as necessary and towards pre-prototype engine.	FY 06	FY 15
⇨	D-101	Descent Engine Performance	Given the expected performance and envelope requirements for the LSAM descent engine, there is a possibility that the engine design will be outside the current techology base of throttling LOX/ H_2 expander cycle engine and fail to satisfy requirements.	3	5	21	Performance	Mark Klem	M	There is continual coomunication with the Altair Project Office to ensure their understanding. A plan has been laid out to address issues. Working with Altair to refine requirements. Waiting on Altair to complete next design cycles. Altair design studies were never completed.	1.0, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6	1) Technology/Advanced Development project to mitigate/demonstrate capability. 2) Identify and compare expected requirements w/ current technology base. 3) Design System including component design, fab, & test, and address issues with component and subsystem testing	FY 06	FY 12
⇨	D-113	Workforce Availability	Given the aging work force leaving agency with limited hiring, at time of FSD contract award, the possibility exists that there will be limited in-house government technical competency for supporting project as "smart buyer".	3	5	21	Schedule	Mark Klem	M	There is difficulty in getting sufficient numbers of civil service workforce with the right competencies to support mitigation efforts. A small amount of hiring has occurred.	1.0	MITIGATE: 1) in-house work (independent tech mat). 2) GTA work supporting risk # PCAD-101 mitigation. 3) In depth insight/oversight of the risk # PCAD-101 mitigation. 4) Hire and train freshouts.	FY 06	FY 15
⇨	G-17	Combustion Stability Characteristics	Given the lack of hot-fire test data with LOx/CH_4; the combustion stability characterisitics of the engine designs has not been validated and predictive methods have not been developed.	3	4	19	Performance	Mark Klem	M	Testing with the Aerojet AME using an instrumented stability test chamber was not completed. One of the injectors tested at sea level developed a 1T combustion instability. The data will be highly valuable to increasing combustion instability phenomena and will be used to update current models.	3.1.3, 3.1.4	Provide test instrumentation and bomb testing to measure instability	FY 06	FY 15
⇨	G-19	Thermal Cycle Limits of Thrust Chambers	Given the requirements for thermal cycling due to multiple engine starts, thermal cycles may lead to a failure of the thrust chamber	3	4	19	Performance	Mark Klem	M	In-house efforts on regenerative cooling proceeding. Fundamental heat tranfer data obtained on individual heated tubes using methane as coolant. Added sea level testing of contractor methane cooled regen chambers under SAA and expanding heat tube testing of methane thermal properties characterization. Testing could not be completed due to injector failure early during testing. No data gained on regen cooled chambers. During pulse testing of a RCE some pitting of the oxidation coating has been observed.	2.1.5, 2.1.6, 3.1.3, 3.6, 3.9.1, 3.9.2, 3.9.4 , 3.11	Gain heat transfer data from AME test, 100-lbf regen RCE testing, sea level testing of contractor regen chambers, testing of high temperature materials and heated tube rig testing	FY 06	FY 12
⇨	G-6	Engine Health Monitoring	Given the limited amount of test data for high cycle components for LOx/CH_4 and likely lack of flight tests; there is the possibility that methods to detect pre-failure modes with health monitoring devices have note been properly tested.	3	4	19	Performance	Mark Klem	W	Some tests conducted but limited data not sufficient to reduce risk at this time. *NO ACTIVE HEALTH MONITORING ACTIVITY*	2.1.6, 3.1.3, 4.1	Collect data from longer duration test activites where the engine components are used repeatedly such as; 100-lbf RCE altitude testing, PWR CECE and Aerojet AME	FY 06	FY 12

Propulsion and Cryogenics Advanced Development (PCAD) 33

PCAD Risk Assessment

Trend Since FY09 IBR	Risk ID and Open Date	Risk Title	Risk Statement (MUST USE - "Given that (state the fact)..there is a possibility (state the concern)... resulting in (state the consequence..)"	L	C	R	Affinity Group (Budget, Performance, Cost, Schedule)	Owner Initiator	Approach (M,W,A,R) Mitigate, Watch, Accept, Research	Status/Context	Mitigation WBS	Mitigation	Estimated Start Date Mitigation	Estimated End Date Mitigation
⇨	C-053	Propellant Delivery to RCS	Given the distributed nature of the RCS feed line within a variable thermal environment, there is the possibility that the propellant condition at the RCS engine inlet will not meet requirements or will cause excessive loss of propellant.	3	3	15	Performance	Mark Klem	M	Testing at WSTF with modified 870-lbf and 100-lbf hardware demonstrated the ability of a Thermal Vent System (TVS) to control propellant delivery. Currently designing Integrated Propulsion System Test Bed (IPSTB) as a parametric rig to examine thermal performance of feedsystems with multiple cryogenic RCE with a single AME operating separately and concurrently. IPSTB design has been delayed and budget cut which has stopped any fabrication.	2.2.2	Further integrated rig testing at WSTF TS401 to understand operation with LOx and LCH_4.	FY 06	FY 12
⇨	D-112	Descent Engine Single Technology Path	Given the desire to have competion at time of RFP, the possibility exists that there will be a limited number (or one) of qualified suppliers for engines that can satisfy the requirements.	2	4	14	Budget	Mark Klem	M	Pintle injector testing is proceeding. Alternate government concepts are being investigated. Unsolicited proposed concepts are promising.	4.1, 4.2, 4.4	MITIGATE: Obtain additional source/concept to reduce risk # PCAD-101 mitigation and provide competition.	FY 06	FY 12
⇨	G-24	High Temperature RCS Materials	Given Aerojet's exception to the RCE EIS MR and selection of columbium for chamber design; the possibility exists that without high temperature chamber materials the main MR range with life will not be demonstrated by test for RCS	2	4	14	Performance	Mark Klem	R	Testing of the Aerojet RCE beyond predicted limiting MR has been conducted. Testing has shown the engine can meet performance levels. During pulse testing some pitting of the oxidation coating has been observed. Further testing is being conducted and a SAA with a coating manufacture is in negotiation for an alternate approach. Testing with new coating is TBD based on receiving additional funds.	2.1.5, 2.1.6, 2.1.9, 3.6	Conduct chamber material research on previous test data and examine data from current Aerojet RCE engine testing. Testing of chambers that incorporate high temperature materials and coatings in FY 10 developed under SBIR and IPP	FY 06	FY 12
⇨	D-91	Technology Assumptions	Given the high performance and reliability requirements combined with desire for low development cost, there is a possibility that technology base assumptions to satisfy each will be inconsistent or conflicting resulting in a failure to meet requirements.	1	5	12	Budget, Performance, Schedule	Mark Klem	W	Coordination meetings were conducted with personnel assessing Cx risks. Data was presented on reliability history of the RL10 in relation to design upgrades and engine performance improvements. There is continual communication with the Altair and Orion Project Offices to ensure their understanding.	1.0	1) Educate (LLPO, and Cx Level II). 2) Analysis of assumptions (reliability, cost, performance). 3) Develop consensus definition of Derivative/Legacy/Clean Sheet engine.	FY 06	FY 15
⇩	G-36	Propellant Quality on RCS Performance	Given gas may exist in the feedsystem; there is a possibility that the pulses of the LOx/methane engines will not be repeatable which is an important GNC requirement.	1	5	12	Performance	Mark Klem	M	Altitude testing with 100-lbf LOx/LCH_4 reaction control engine and propellant conditioning system was completed. Testing demonstrated engine performance over a range of propellant inlet conditions and mixture ratios. Testing was conducted in both steady state and pulse operations.	2.1.5, 2.1.6, 2.1.9, 2.2.2	Conduct integrated engine and feedsystem tests	FY 06	FY 12

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PCAD Risk Assessment

Trend Since FY09 IBR	Risk ID and Open Date	Risk Title	Risk Statement (MUST USE - "Given that (state the fact)..there is a possibility (state the concern)... resulting in (state the consequence..)"	L	C	R	Affinity Group (Budget, Performance, Cost, Schedule)	Owner Initiator	Approach (M,W,A,R) Mitigate, Watch, Accept, Research	Status/Context	Mitigation WBS	Mitigation	Estimated Start Date Mitigation	Estimated End Date Mitigation
⇩	D-102	Descent Throttle Response	Given the engine out requirement to the LSAM descent stage, there is a possibility that the engine/ system response time will not be fast enough to maintain control of the vehicle for landing resulting in a crash or need to abort.	1	5	12	Performance	Mark Klem	M	Testing during the CECE Demo 1.7 demonstrated chamber pressure and mixture ratio authority closed-loop control achieved over a wide range of throttled power, fast throttle ramp rates, minimum power starts down to a smooth start to 10% power, high power-high mixture ratio operation, ignition testing achieved for extremely cold starts with min lox/max fuel and max lox/min fuel, 11 rapid relights , many achieved as 2 relights within the same test matrix run.	4.1, 4.2, 4.3 4.4, 4.5, 4.6	MITIGATE: 1) Stage descent control study to identify requirements; 2) Incorporate requirement into risk # PCAD-101; 3) Initiated study of additonal work on throttling valve and control system technologies	FY 06	FY 12
⇩	G-13	Lack of Data for Computational Models	Given there is minimal performance data with LOx/CH_4, computational models have not been validated for performance predictions or thermal analysis	2	4	11	Performance	Mark Klem	M	Sea level and altitude data has been obtained on both reaction control systems and main engines. Main engine data was not as extensive as planned so more work required. Reaction control testing has verified steady state and pulse performancce at altutide. Testing at thermal conditions (cold and warm) has not yet been completed and currently no budget is available for testing.	2.1.5, 2.1.6, 2.1.9, 2.2.2, 3.1.3, 3.2.4, 3.2.5, 3.2.7, 3.6, 3.8, 3.9.1, 3.9.2, 3.9.3, 3.9.4, 3.10.1, 3.11	Per the existing LOx/CH_4 Main Engine and RCS contracts, gather transient and steady-state combustion data and update generic LOx/CH_4 models to incorporate empirical data. Incorporate government basic test data for analysis.	FY 06	FY 15
⇩	G-31	Lightweight Exciters	Given that there are no existing space qualified RCS exciters and both RCS contractors have not been able to engage industry; the possibility may exist that the industry base has eroded and will not support engine delivery.	2	4	11	Schedule	Mark Klem	M	NASA has completed altitude ignition testing with compact exciters from both a phase II SBIR (Alphaport) and a Unison/Aerojet design. Testing was conducted at altitude in a LOx/LCH_4 igniter test fixture which simulates an engine configuration. Both units performed well, igniting over a wide range of conditions with no "no lights". Plan is to install a Unison/Aerojet exciter on a 100-lbf reaction control engine and test at altitude.	2.1.1	Continue exciter work with Aerojet under RCS contract, in-house activities, and phase II SBIR to bring electronics-on-plug concept to maturity sufficient for prototype engine delivery. Concepts will be integrated into existing igniter rigs/engines and tested at altitude with LOx/LCH_4 propellants	FY 06	FY 11
⇩	G-4	Wide Inlet Operating Conditions	Given that the engine end-item-specifications require a wide range of propellant conditions (T, P); the possibility exists that the engine contractor and government facilities can not create the conditions necessary to verify all requirements.	2	4	11	Performance	Mark Klem	M	NASA currently designed and tested a propellant conditioning system to expand test capabilities for both sea level and vacuum testing. the propellant conditioning facility system (PCFS) previously developed under PCAD was utilized. The PCFS conditioned the propellants to a specified temperature in less than one hour. The system maintained the set point temperature to within +/- 5°R up to the thruster valve inlet. Liquid oxygen temperatures ranged from 160-224R and liquid methane temperatures ranged from 170-224R.	2.1.5, 2.1.6, 2.1.9	Perform testing within the capabilities of the contractor test facilities and use the propellant conditioning system at ACS.	FY 06	FY 12
⇩	D-94	Throttling Performance	Given that the engine must meet a certain performance requirement across a given throttle range for mission success, there is a possibility that these requirements may not be met. (Current experience base shows approximately 2% Isp degradation at 50% power)	2	4	11	Performance	Mark Klem	M	Testing with the RL10 based Common Extensible Cryogenic Engine (CECE) through 4 demonstrations has demonstrated the performance losses at lower power settings can be minimized. Performance levels appear to be sufficient for current mission plans. Also, combustion efficiency testing of a pintle injector at sea level showed good performance at low power points.	4.1, 4.2, 4.3 4.4, 4.5, 4.6	MITIGATE: refer to mitigation in risk # PCAD-101	FY 06	FY 12

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PCAD Risk Assessment

Trend Since FY09 IBR	Risk ID and Open Date	Risk Title	Risk Statement (MUST USE - "Given that (state the fact)..there is a possibility (state the concern)... resulting in (state the consequence..)"	L	C	R	Affinity Group (Budget, Performance, Cost, Schedule)	Owner Initiator	Approach (M,W,A,R) Mitigate, Watch, Accept, Research	Status/Context	Mitigation WBS	Mitigation	Estimated Start Date Mitigation	Estimated End Date Mitigation
⇩	D-89	Stable Deep Throttling	Given that the engine must be able to support deep throttling in order to perform the mission, there is a possibility that it will not be able to meet the deep throttling requirements.	1	4	8	Performance	Mark Klem	M	CECE Demo 1.7 testing with insulated injector demonstrated low power stability, including chug-free operation down to 5.9% power, or 17.6:1 overall cryogenic deep throttling demonstrated in a complete expander cycle engine system, with all system-level interactions greatly enhancing the value of the technology database acquired. Sea level pintle injector tests successfully demonstrated stable throttling to 10:1 with minimal performance losses.	4.1, 4.2, 4.3, 4.4, 4.5, 4.6	MITIGATE: refer to mitigation in risk # PCAD-101 Risk includes effects of system operational controlability and thrust chamber stability characteristics (acoustic and chug) as well as turbopump stall and rotordynamic margins.	FY 06	FY 12
⇩	G-35	RCS Igniter Integration with Main Stage	Given that there are two engine propellant valves feeding four sets of passages (igniter and main injector); there is a possibility that propellants will not reach the igniter sufficiently before the main.	1	4	8	Performance	Mark Klem	M	Altitude testing with 100-lbf LOx/LCH$_4$ reaction control engine with bipropellant valves and propellant conditioning system was completed. Testing demonstrated engine performance over a range of propellant inlet conditions and mixture ratios. Testing was conducted in both steady state and pulse operations. Thermal Vacuum testing of the RCE at extreme conditions is TBD based on funding.	2.1.3, 2.1.5, 2.1.6, 2.1.9, 2.2.2	Test timing of RCE over a range of propellent inlet conditions and vary thermal exposure of engine during altitude testing	FY 06	FY 12
⇨	D-97	Deep Throttle Engine - Unclear Requirements	Given that the LSAM descent and ascent engine requirements are unknown or unclear, LOx/ H_2 Deep Throttled Engine Project may be investing effort in wrong area.	1	4	8	Budget	Mark Klem	W	PCAD tasks coordinated extensively with Altair Project Office.	1.0	Watch Altair Requirements	FY 06	FY 15
⇩	G-15	Ignition Reliability/Experience	Given that the ignition characteristics of LOx/CH$_4$ are uncertain due to global lack of experience w/ LOx/CH$_4$, the engine/igniter designs may not achieve the startup reliability required.	1	3	5	Performance	Mark Klem	M	Significant amount of sea level testing was conducted with Spark Torch Igniters and Catalytic Igniters. Testing to date has shown no significant issues at sea level for a torch to ignite a chamber. No-light issues to date appear to be manufacturing related. 30,000 RCS igniter tests were successful. Altitude testing with 100-lbf LOx/LCH$_4$ reaction control engine with bipropellant valves and propellant conditioning system was completed. Completed altitude testing with a 5,500-lbf main engine at WSTF and did not have any ignition related problems. Testing demonstrated engine performance over a range of propellant inlet conditions and mixture ratios. Testing was conducted in both steady state and pulse operations.	2.1.1, 2.1.3, 2.1.5, 2.1.6, 2.1.9, 2.2.2, 3.1.3	For the Main Engine, explore various ignition technologies via existing contracts (spark-initiated torch and catalytic-initiated torch) and in-house work. Sea level and altitude testing at the component level and integrated into combustion chambers	FY 06	FY 12

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PCAD Transition Activities

PCAD Contracts

- **Aerojet Ascent Main Engine – Closeout November 6, 2010**
  - Final Report Due Aug 30, 2010
  - Final property accounting in process
  - All current deliverables posted on Windchill (AME Aerojet Contract)
- **Aerojet 100-lbf RCE – Closeout Sept 30, 2010**
  - Final report due July 31, 2010
  - Outstanding Deliverables:
    - Unison DAT exciters due Sept 2010
    - 10 Refurbished valves due Sept 2010
  - COTR working to property accounting and verify all deliverables have been received
  - All data and deliverables posted on Windchill (Aerojet RCE Drop Folder)
- **NGAS 100-lbf RCE – Closeout Sept 30, 2010**
  - Final report due Aug 30, 2010
  - Thermal analysis model and users manual due Sept 30
  - COTR working to verify all deliverables have been received
  - All data and deliverables posted on Windchill (ETDP-Propulsion/NGAS RCE folder)

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PCAD Contracts

- **PWR CECE – Closeout July 30, 2010**
  - Final property accounting in process
    - COTR is attempting to maintain control of insulated injector for possible future use with PWR. Government equipment is imbedded in CECE and will cost money (~$100k) to extract. The cost for extraction is not worthwhile, but an agreement to keep the hardware available for 3 years for future NASA work is being pursued.
  - Final report due July 30, 2010
  - All data and deliverables posted on Windchill (HESS-1020-Deep Throttling Common Engine)
- **NGAS Pintle – Closeout February 28, 2011**
  - Actuator design in process – CDR in August 2010;
  - Actuator hardware – January 2011
  - Final report – February 2011
  - All NASA hardware in storage at MSFC
  - All data and deliverables posted on Windchill (PPCS-718-Thrust Pintle Eng)
- **Aerojet Two Stage Injector – Closeout March 29, 2011**
  - Injector Fabrication and delivery in March 2011
  - All current deliverables posted on Windchill (Aerojet – Descent Throttling Injector)

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PCAD In-House

- PCAD Project
  - All documents posted on Windchill (ETDP – Propulsion Technology)
- MSFC Testing
  - Data stored on central servers at NASA MSFC and on PCAD Windchill site.
  - All hardware in storage at MSFC per center level procedures
- GRC Testing
  - Data stored on central servers at NASA GRC and on PCAD Windchill site.
  - All hardware in storage at GRC per center level procedures
- JSC/WSTF Testing
  - Data stored on central servers at NASA WSTF and on PCAD Windchill site.
  - All hardware in storage at WSTF per center level procedures

PCAD Publications and Outreach

- **84 PCAD Papers Completed**
  - **50 JANNAF Papers**
    - **Best Paper:** 2008 JANNAF 6th Modeling and Simulation Subcommittee / 4th Liquid Propulsion Subcommittee / 3rd Spacecraft Propulsion Subcommittee Joint Meeting in Dec 2008. "An Update on the Development of the Development of NGC's TR408, 100-lbf Reaction Control Engine" - Mark Trinidad (NGAS), Bill Studak (JSC) and Gordon Dressler (NGAS)
  - **11 AIAA Papers**
  - **1 SAE Paper**
  - **3 International Papers**
  - **12 NASA TM or CR**
  - **7 Internal and contract deliverables**
- **4 Videos**
- **10+ Press Releases**
- **12 Students**
- **2 Brochures**

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Lessons Learned

- **Multiple approaches to risk reduction should be carried at all levels of technology maturation**
  - Ablative v. regen for ascent engines
  - CECE, Pintle, Dual Manifold for descent engines
  - Unison, Alphaport, in-house for exciters
- **Agreements early in project on requirements is necessary.**
  - Lack of Cx requirements to focus technology
- **Clear guidance on application of agency policies is required.**
  - 7120.8 and 7123 issues
- **Clear communication and coordination between programs and center management on reporting requirements**

Thank You for everything the last five years. It has been a pleasure working in this program

Mark, Tim, Ken, Marilyn, Lori, and the entire PCAD team

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The End

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PCAD FY10 Accomplishments

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Variable Energy Exciter (VEE) Breadboard Demonstration Test (MS PCAD 2.1-03)

PT: PCAD
PM: Mark Klem
PI: Charles Sarmiento (GRC)

Objective:

Develop a compact exciter design that would realize reduced weight, volume and complexity from current state-of-art designs available for engine applications.

Key Accomplishment/Deliverable/Milestone:

- Developed a hybrid, variable-energy exciter (VEE) spark ignition breadboard which uses inductive energy storage for high-voltage (ionization) pulse generation along with capacitive energy storage to supply fixed-energies for the resulting sparks.
- Tested in altitude environment at NASA Glenn, RCL 21, with liquid oxygen/liquid methane 870-lbf engine igniter test hardware.
- Achieved ignition in 51 of 52 attempts.
  - Spark energy settings were 33, 39 and 45mJ
  - Pulse testing was at 160msec with 200 sparks/sec
  - Ignition chamber pressures were 230-290 psia
  - Oxygen flow rates were 0.015-0.073 lb_m/sec at 180-200R
  - Methane flow rates were 0.008-0.051 lb_m/sec at 210-225R
- Examined the impacts that spark energy had on the ability to ignite and the corresponding ignition time delay.

NASA GRC Variable Energy Exciter

Variable Energy Exciter (VEE) at GRC RCL21

Significance:

- Reduces the weight and complexity of the ignition system
- Eliminates high voltage connection line

Propulsion and Cryogenics Advanced Development (PCAD)

Complete 100-lbf LOx/LCH_4 RCE altitude performance testing (MS-PCAD 2.1-10)

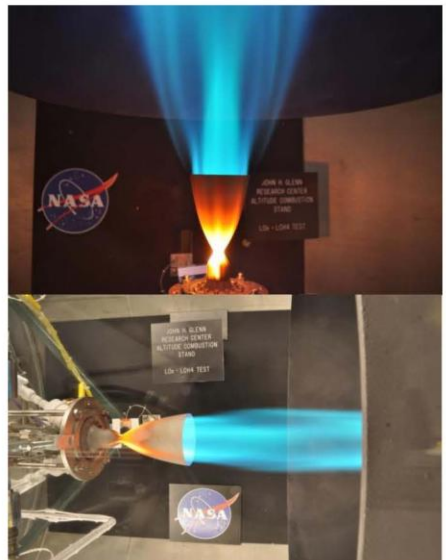
PT: PCAD
PM: Mark Klem
PI: Bill Marshall and Julie Kleinhenz (GRC)

Objective:

Develop a detailed understanding of operational envelope characteristics of the Aerojet 100-lb_f reaction control engine (RCE) by directly measuring performance, thrust and vacuum specific impulse (Isp), under various propellant inlet conditions at altitude with mixture ratio excursions above and below the RCE 2.5 MR design point.

Key Accomplishment/Deliverable/Milestone:

- Completed 60 altitude hot-fire tests with Aerojet 100-lb_f liquid oxygen/liquid methane (LOx/LCH_4) engine and propellant conditioning feed systems (PCFS)
  - Radiation cooled columbium 45:1 area ratio nozzle
- Testing conducted in the Altitude Combustion Stand at NASA GRC
- Obtained key data on thrust, combustion performance (C*), and vacuum specific impulse (Isp_v)
- Mixture ratios were varied from the RCE design point mixture ratio (MR) of 2.5 by +/-0.5
- Tests were run over a range of propellant inlet conditions:
  - Nominal (204 °R LOx/204 °R LCH_4)
  - Cold/cold (160 °R LOx/170 °R LCH_4)
  - Warm/warm (224 °R LOx/224 °R LCH_4)



Aerojet 100-lbf LOx/LCH_4 reaction control engine in test at NASA GRC ACS

Significance:

- Testing over wide operating range demonstrates that LOx/Methane propulsion systems can be reliable for conditions encountered during a range of space operations.
- Data will be supplied to potential customers as input to propellant selection trade study processes

Propulsion and Cryogenics Advanced Development (PCAD)

Unison Exciter Prototype LOx/LCH_4 Hot-fire Demonstration (MS PCAD 2.1-13)

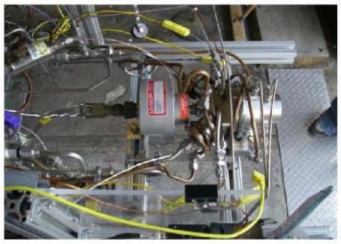
PT: PCAD
PM: Mark Klem
PI: Charles Sarmiento (GRC)

Objective:

LOx/LCH_4 hot-fire demonstration of a prototype testing proof-of-concept (PoC) exciter design in an altitude environment with an 870-lbf igniter

Key Accomplishment/Deliverable/Milestone:

- Demonstrated a 40 millijoule Aerojet/Unison proof-of-concept exciter with an 870-lbf engine torch igniter on LOx/LCH_4 at altitude..
- Achieved ignition in 231 of 231 attempts at nominal conditions
- Exciter operation and ignition performance were evaluated
  - Commanded sparking durations (8 to 95 ms),
  - Exciter input voltages (23, 28, & 36 Vdc),
  - Inlet propellant conditions:
    - Pressure: 275, 300, 325, & 350 psia oxygen/methane tank sets
    - Temperatue: 165-190 R oxygen and 210-240 R methane
- Completed both single shot and 5-10 pulse string (11% duty cycle) tests.
- Results indicate an optimal window or "sweet-spot" for ignition during the igniter flow ramp/pressure rise and the importance of delivering multiple, full energy sparks during this window to achieve fast and reliable ignition



Aerojet/Unison proof-of-concept (PoC) compact exciter installed with adapter onto 870-lbf igniter at GRC RCL-21 facility

Aerojet/Unison proof-of-concept (PoC) compact exciter

Significance:

- Reduces the weight and complexity of the ignition system
- Eliminates high voltage connection line from power source to engine pod. Reduces potential for electrical interference.

Propulsion and Cryogenics Advanced Development (PCAD)

Complete vacuum impulse bit testing of a 100-lbf LOx/LCH_4 reaction control engine(MS-PCAD 2.1-16)

PT: PCAD
PM: Mark Klem
PI: Bill Marshall and Julie Kleinhenz (GRC)

Objective:

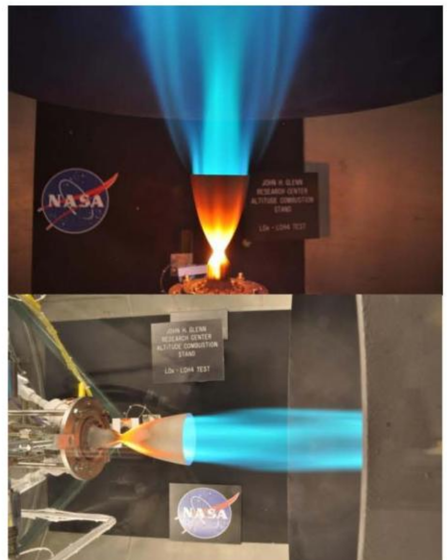
Vacuum testing over a range of propellant inlet conditions of a 100-lbf LOx/LCH_4 reaction control engine to determine pulse (impulse bit) performance

Key Accomplishment/Deliverable/Milestone:

- Pulse trains of up to 10 pulses over a range of duty cycles were conducted at each propellant inlet condition, and tests with 30-pulse trains were conducted at nominal conditions.
- Testing conducted in the Altitude Combustion Stand at NASA GRC
- Obtained key data on pulse impulse bit (Ibit) to determine general trends over a range of propellant inlet conditions.
- Achieved a minimum I-bit requirement (4 lbf-sec) with a series of 40 msec pulses at nominal propellant temperature
- Tests were run over a range of propellant inlet conditions:
  - Nominal (204 °R LOx/204 °R LCH_4)
  - Cold/cold (165 °R LOx/190 °R LCH_4)
  - Warm/warm (224 °R LOx/224 °R LCH_4)

Significance:

- Testing over wide operating range demonstrates that LOx/Methane propulsion systems can be reliable for conditions encountered during a range of space operations.
- Data will be supplied to potential customers as input to propellant selection trade study processes



Aerojet 100-lbf LOx/LCH_4 reaction control engine in test at NASA GRC ACS

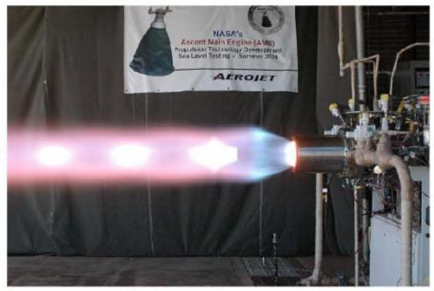
Propulsion and Cryogenics Advanced Development (PCAD)

Aerojet AME workhorse engine sea level test complete (APG 10AC16)(MS-PCAD 3.1-03)

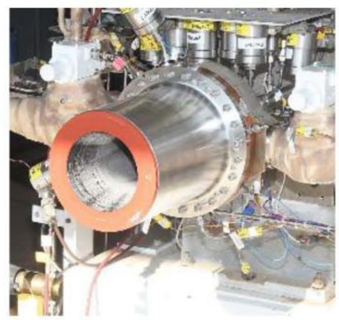
Objective:

Complete sea level performance (C*) and high frequency stability pulse gun testing at Aerojet of a 5,500-lbf LOx/LCH_4 Ascent Main Engine (AME) workhorse engine.

Key Accomplishment/Deliverable/Milestone:



- Aerojet fabricated three injectors for ascent main engine testing.
  - Two injector face pattern designs and three wall cooling configurations
  - Injector 1-rev 1 (48 total tests at sea level) delivered to WSTF for altitude testing, combustion performance lower than target. Injector 2 experienced excessive heating (7 tests) and Injector 1-rev 2 encountered combustion instability (6 tests)
- Copper and columbium stability resonators
- Spark torch ignition system
- 8-inch and 10-inch length silica-phenolic ablative combustion chambers
  - 1.9:1 sea Level nozzle exit area ratio
- Commercial off the shelf Flodyne cryogenic propellant valves
- Key operating parameters
  - Pc = 250 psia
  - Thrust = 5500 lbf
  - Design Mixture Ratio = 3.0
  - 6-inch diameter copper injector face



Significance:

- Hardware is enabling for both sea level and altitude testing to obtain performance data which will be supplied to vehicle system modelers and used for performance model validation

Propulsion and Cryogenics Advanced Development (PCAD)

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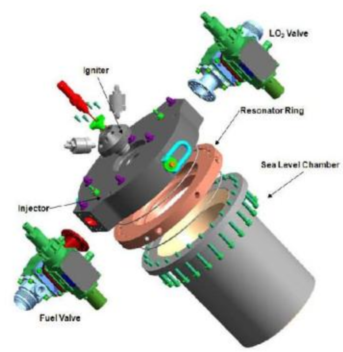
Aerojet AME workhorse engine sea level engine for altitude test (MS-PCAD 3.1-04)

Objective:

Deliver injector, chamber and valves to complete sea level performance (C*) and high frequency stability pulse gun testing at Aerojet of a 5,500-lbf LOx/LCH_4 Ascent Main Engine (AME) workhorse engine .

Key Accomplishment/Deliverable/Milestone:

- Aerojet fabricated three injectors for ascent main engine testing.
  - Two injector face pattern designs and three wall cooling configurations
  - One injector delivered to WSTF for altitude testing, but has low combustion performance. One injector experienced excessive heating and another encountered combustion instability
- Copper and columbium stability resonators
- Spark torch ignition system
- 8-inch and 10-inch length silica-phenolic ablative combustion chambers
  - 1.9:1 sea Level nozzle exit area ratio
- Commercial off the shelf Flodyne cryogenic propellant valves
- Key operating parameters
  - Pc = 250 psia
  - Thrust = 5500 lbf
  - Design Mixture Ratio = 3.0
  - 6-inch diameter copper injector face



Significance:

- Hardware is enabling for both sea level and altitude testing to obtain performance data which will be supplied to vehicle system modelers and used for performance model validation

Propulsion and Cryogenics Advanced Development (PCAD)

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Aerojet LOx/LCH4 Ascent Main Engine (AME) workhorse engine altitude testing MS-PCAD 3.1-06)

Objective:

Complete altitude performance testing at WSTF TS401 of a 5,500-lbf LOx/LCH_4 Ascent Main Engine (AME) workhorse engine to determine specific impulse (Isp), altitude ignition characteristics and ablative chamber life.

Key Accomplishment/Deliverable/Milestone:

- Aerojet Injector 1-rev 1 was used for all altitude testing at WSTF
  - Test cell run at 0.025 psia or approximately 145,000 ft of altitude
- Total of 187 seconds of run time on engine
  - Seven 20-sec tests and one 40-sec test
- 8-inch long silica-phenolic ablative combustion chambers with Shuttle OME nozzle extension. Total Area Ratio 129:1
- Performance
  - Measured: 345.8-sec Isp at 129:1
  - Extrapolated to 150:1 design point: Isp~ 348-sec
- Key target operating parameters
  - Pc = 250 psia with 325 psia propellant inlet pressures to the valves
  - Vacuum specific impulse – 355 -sec
  - Thrust = 5500 lbf
  - Design Mixture Ratio = 3.0

Aerojet LOx/LCH4 5,500-lbf workhorse engine in test at NASA White Sands Test Facility

Significance:

- First tests to demonstrates performance levels that can be obtained with a 5,500-lbf LOx/Methane engine
- Provides critical data to improve analytical models and predictive capabilities for future LOx/Methane propulsion systems.
- Data will be supplied to potential customers as input to propellant selection trade study processes

Propulsion and Cryogenics Advanced Development (PCAD)

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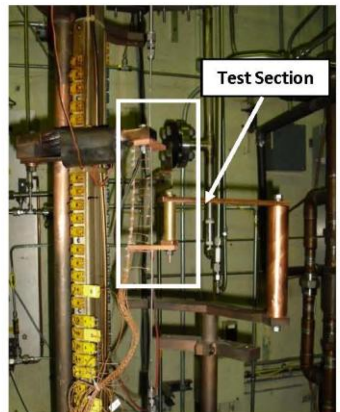
Heated tube two phase methane heat transfer characterization (MS-PCAD 3.9-02)

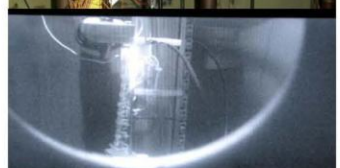
Objective:

Produce heat transfer correlations for liquid and two-phase methane for a variety of coolant channel flow rates and heat fluxes.

Key Accomplishment/Deliverable/Milestone:

- Completed 22 test runs with 4 different tube samples.
- Data includes
  - Test section inlet and outlet temperature and pressure data to discern the methane state (liquid, 2-phase,or gas) and corresponding enthalpy.
  - Fluid flow rate with over 10 thermocouples along the test section to measure the temperature and characterize the local heat flux into the methane.
- Test samples were Inconel 600 with 5 inches actively heated.
  - Two were with an inner diameter (ID) of 0.083-in., one with an ID of 0.056-in. and one with an ID of 0.026-in. All had wall thicknesses of 0.020-in.
- Coolant pressure in the test samples ranged from 200 to 500psi
- Maximum test sample was 2007°R
- Large pressure drops are experienced for test sections with inner diameters of 0.056-in. and smaller.
- Heat fluxes up to 7.7 BTU/in^2 sec were achieved using liquid methane




Tube during test in chamber

Significance:

- First heat transfer data to characterize regimes relevant to the design and development of methane regeneratively cooled engines
- Key design data on maximum heat loads that liquid methane can tolerate and still effectively cool the engine

Propulsion and Cryogenics Advanced Development (PCAD)

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LOx/Methane Transpiration Cooled Chamber Fabrication (MS-PCAD 3.11-01)

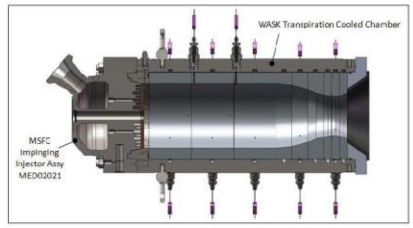
PT: PCAD
PM: Mark Klem
PI: Joel Robinson

Objective:

Complete fabrication of a 6000-lbf class LOx/Methane transpiration cooled combustion chamber for sea level testing

Key Accomplishment/Deliverable/Milestone:

- Under a Phase III SBIR, WASK fabricated a methane transpiration cooled chamber for testing with an existing injector.
- Hot-fire data will be used to compare injector performance from previous data to evaluate implications of cooling approach.
- Hardware will have 5 main-stage tests over various chamber pressures and mixture ratios.
- Technology is considered an alternative to ablative and regenerative concepts.
  - Fabrication time is shorter for transpiration chambers than regen chambers.
  - Ultimate performance implications would need to be evaluated with a follow-on vacuum test program.



WASK 9 segment transpiration cooled combustion chamber

WASK engineer adjusting manifold leg flowrates for each of segments

Significance:

- Provides hardware to obtain critical data to improve analytical models and predictive capabilities for future LOx/Methane propulsion systems.
- Data will be supplied to potential customers as input to propellant selection trade study processes
- First large scale production of a methane transpiration cooled combustion chamber

Propulsion and Cryogenics Advanced Development (PCAD) 54

Demo 1.7 CECE Testing Complete (MS - PCAD 4.1-06)

PT: PCAD
PM: Mark Klem
PI: Tony Kim

Objective:

The Pratt & Whitney Rocketdyne (PWR) Common Extensible Cryogenic Engine (CECE) is focused on demonstrating technologies for a deep throttling (10% power) liquid oxygen/liquid hydrogen cryogenic engine for the descent stage of a landing vehicle. CECE leverages the flight-proven RL10 engine as a point of departure, inserting advanced technologies to achieve key enabling capabilities, including, but not limited to: deep throttling, high reliability, safety, restarts, and durability

Key Accomplishment/Deliverable/Milestone:

- Completed Demo 1.7 Insulated Injector testing at the PWR facility E6 test stand in West Palm Beach on April 17, 2010.
- Successfully completed 8 tests for 20 hot fire runs which explored the following operating points
  - Chamber pressure and mixture ratio authority closed-loop control over a wide range of throttled power
  - Fast throttle ramp rates
  - Minimum power starts successively accomplished down to a smooth start to 10% power
  - High power, high mixture ratio operation
  - Ignition testing successfully achieved for extremely cold starts with min lox/max fuel and max lox/min fuel, including 11 rapid relights.
  - Low power stability demonstrated, including chug-free operation down to 5.9% power
- Data achieved was from 104% to 5.9% power, or a 17.6:1 throttling range - a significant increase over the 13:1 previously.
- Demo 1.7 engine run time completed 2403.0 seconds (40 minutes).
  Total CECE Demo engine run time to-date is 7435.8 seconds (123.9 minutes).

Significance:

- Throttling Liquid Oxygen / Liquid Hydrogen lunar lander descent engine is mission enabling for the Exploration lunar architecture.
- Results will be used to examine mission scenarios and evaluate future technology requirements for future space mission

Propulsion and Cryogenics Advanced Development (PCAD)

Pintle Injector Test Series 2-Calorimeter Complete (MS - PCAD 4.2-02)

PT: PCAD
PM: Mark Klem
PI: Tony Kim (MSFC)

Objective:

Development of deep throttling liquid oxygen (LOx) / liquid hydrogen (LH_2) pintle injector technology, applicable across a broad range of thrust and mixture ratio (MR). Demonstrate high performance and combustion stability over a 10:1 throttle range with a pintle injector test bed.

Key Accomplishment/Deliverable/Milestone:

- Total of 46 sea level hot fires were conducted with different Pintle configurations using liquid oxygen and gaseous hydrogen.
- Completed 30-second duration high-power test which demonstrated hardware durability
- Completed extensive Design Of Experiments (DOE) for optimized injector performance
- Throttled Pintle Injector from 100% to 10% at discrete power levels with no indication of combustion instability.
- Testing conducted with a water cooled calorimeter combustion chamber
- Combustion efficiencies (ηC^*) of 98% or better performance achieved.
- Testing was conducted at NASA MSFC on TS116.

Water cooled calorimeter hardware installed in test stand for Pintle injector testing

Significance:

- Demonstrates pintle injector combustion performance over a wide of power conditions.
- Throttling Liquid Oxygen / Liquid Hydrogen lunar lander descent engine is mission enabling for the lunar architecture.
- Results will be used to examine mission scenarios and evaluate future technology requirements for Altair

Hot-Fire test of a pintle injector with a water cooled calorimeter combustion chamber at MSFC TS116

Propulsion and Cryogenics Advanced Development (PCAD) 56

Complete Advanced Turbine Bypass Valve (ATBV) Testing (MS-PCAD 4.3-01)

PT: PCAD
PM: Mark Klem
PI: Nick Case (MSFC)

Objective:

Characterize the actual effective flow area versus valve position at nine equally spaced points in the valve travel and determine valve and seal performance under deep throttling engine conditions in preparation for future throttling engine system testing.

Key Accomplishment/Deliverable/Milestone:

The Test Series Completed (35 Tests - 50 data points)

- Flow Characterization Tests(27 tests - 27 data points)
  - Unchoked Flow Tests (20 tests- 20 data points)
  - Choked Flow Tests (7 tests - 7 data points)
- Engine Performance Tests (8 tests – 12 data points)
  - Steady State Engine Tests (6 tests - 6 data points)
  - Engine Power Level Sweep Tests (2 tests – 6 data points
- Determined a flow coefficient (C_v) curve for accurately predicting valve flow versus position for use during descent engine modeling and engine testing
- Demonstrated overall valve design and seal performance at simulated engine conditions
- Demonstrated valve performance during transient conditions by simulating engine power level sweeps

ATBV with Servo-Hydraulic Actuator

ATBV during Engine Performance Testing

Significance:

- ATBV actuator performance and force data can be applied to future advanced actuator development and testing
- Flow characterization methods and procedures can be applied to future throttling control valves

Propulsion and Cryogenics Advanced Development (PCAD)

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Complete LOx/LH_2 Two Stage Injector Testing (MS-PCAD 4.4-01)

PT: PCAD
PM: Mark Klem
PI: Gregg Jones (

Objective:

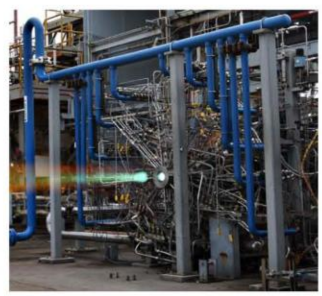
Demonstrate stable 10:1 deep throttling, ignition characteristics, heat transfer and quantify combustion performance (C*) at variable power levels for a LOx/LH_2 throttling two-stage injector

Key Accomplishment/Deliverable/Milestone:

The Test Series Completed (29 Tests - 68 data points)

- Injector with ablative chamber (8 tests - 13 data points)
- Injector with water cooled calorimeter chamber (15 tests - 48 data points)
  - Two-stage injector heat flux measured
  - Longer duration tests conducted with more throttle points (both up and down)
  - Three secondary cavity purge methods were evaluated
- Injector with water cooled calorimeter chamber and torch ignition (6 tests - 7 data points)
  - Verified reliable impinging igniter ignition with the two-stage injector in preparation for LLDE test bed operation
  - Conducted max power test (84 % power level)
  - Further investigation of chug at low power

Two-Stage Injector with Ablative Chamber



Two-Stage Injector with Calorimeter During Hot-Fire Test

Significance:

- Demonstrates two-stage injector operation & combustion performance over a wide range of power conditions.
- Promising high performance combustion efficiency at low power levels
- Results will be used to examine mission scenarios and evaluate future technology requirements for future space vehicles

Propulsion and Cryogenics Advanced Development (PCAD)

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PCAD Bibliography

PCAD Papers

Title	Author(s)	Organization	Meeting	Date (Mon-Yr)	Number
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Northrop Grumman TR202 LOX/LH2 Deep Throttling Engine Technology Project Status	Jason M. Gromski, Annik N. Majamaki, Silvio G. Chianese, Vladimir D. Weinstock, and Tony S. Kim	NGAS	AIAA Joint Propulsion Conference, Nashville, TN	Jul-10	AIAA -
CECE: Expanding the Envelope of Deep Throttling Technology in Liquid Oxygen/Liquid Hydrogen Rocket Engines for NASA Exploration Missions	Victor J. Giuliano, Timothy G. Leonard, Randy T. Lyda, and Tony S. Kim	PWR	AIAA Joint Propulsion Conference, Nashville, TN	Jul-10	AIAA -
Performance and Stability Analyses of Rocket Thrust Chambers with Oxygen/Methane Propellants	Hulka and Jones	MSFC	AIAA Joint Propulsion Conference, Nashville, TN	Jul-10	AIAA -
Liquid Oxygen/Liquid Methane Component Technology Development at MSFC	Robinson	MSFC	ESA/Association Aeronautique Astronautique de France (3AF) - Spain	May-10	M09-0136/M10-0365
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NOFB COLT Engine Development and Testing	G. Mungas , Fisher, London and Fryer	Firestar	5th JANNAF Liquid Propulsion Meeting, Colorado Springs, CO	May-10	
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Design and Development of a 5,500-lbf LOX/LCH4 Ascent Main Engine	Robinson, Veith, Linne, and Robinson	Aerojet	5th JANNAF Liquid Propulsion Meeting, Colorado Springs, CO	May-10	
Altitude Testing of an Ascent Stage LOX/ Methane Main Engine	Stiegemeier, Williams, Melcher and Robinson	GRC	5th JANNAF Liquid Propulsion Meeting, Colorado Springs, CO	May-10	
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Combustion Instability of Swirl Coaxial Element Injectors with Liquid Oxygen/Liquid Methane Propellants	Hulka	MSFC	5th JANNAF Liquid Propulsion Meeting, Colorado Springs, CO	May-10	M10-0499/M10-0500
LOX/LCH4 Igniter Pulse Durability - Test Results Combined Phase I and Phase II	Schneider	GRC	5th JANNAF Liquid Propulsion Meeting, Colorado Springs, CO	May-10	TM-2010-216083

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Propulsion and Cryogenics Advanced Development (PCAD) 61

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CECE Cryogenic Deep Throttling Demonstrator Engine Development Status	Giuliano, Leonard, Kim	PWR	4th JANNAF Liquid Propulsion Meeting, Orlando, FL	Dec-08	
Throttling Characteristics of an RL-10-A-4 Derivative Engine	Leahy, Hulka, Adamski, Freese	MSFC	4th JANNAF Liquid Propulsion Meeting, Orlando, FL	Dec-08	
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Liquid Oxygen / Liquid Methane Testing of the RS-18 Lunar Ascent Engine at Simulated Altitude Conditions at NASA White Sands Test Facility	Melcher , Allred, Cabiran	JSC	4th JANNAF Liquid Propulsion Meeting, Orlando, FL	Dec-08	
Test of Gaseous Oxygen/Gaseous Methane Ignition and Engine Risk Reduction Technologies	Greene, Horn, Farhangi, Hagelston, Schoenberg	PWR	4th JANNAF Liquid Propulsion Meeting, Orlando, FL	Dec-08	
Gox/Methane Ignition and Engine Risk Reduction	Horn, Green	PWR	PWR Contract Final Deliverable	Oct-08	RD08-179
LOX/LCH4 Impinging and Microwave Igniter Vacuum Testing at Test Stand 115	Osborne, Elam, Peschel, Bell, Nichols, Sprader	MSFC	MSFC Internal	Sep-08	MSFC P7063
TR202 Variable Thrust Pintle Descent/Ascent Engine (Cumulative Through Phase II, Option I)	Majamaki, Chianese	NGST	NASA CR	Sep-08	NASA/CR 2008-215472
100-lbf LO2/LCH4 Reaction Control Engine Technology Development	Robinson, P. J., Veith, E. M., Hurlbert, E. A., Jimenez, R., Smith, T.D.,	Aerojet	59th International Astronautical Congress (IAC) - Glasgow, Scotland	Sep-08	
Test Summary Report for Test Program P2514 "6 inch LOX/LCH4 Injector Demonstration"	Sandra Elam, Cynthia Sprader	MSFC	NASA TM	August-08	NASA/TM 2008-215470
LOX/LCH4 Demonstration with Coaxial Injectors - Test Program P7061	Elam, Sprader	MSFC	MSFC Internal	July-08	TR ET10-08-01
LOX/Methane Main Engine Igniter Tests and Modeling	Breisacher/Ajmani	GRC	AIAA Joint Propulsion Conference, Hartford, CT	Jul-08	AIAA-2008-4757 NASA/TM 2008-215421
Liquid Oxygen / Liquid Methane Testing of the RS-18 Lunar Ascent Engine at Simulated Altitude Conditions at NASA White Sands Test Facility	Melcher/Allred	JSC/WSTF	AIAA Joint Propulsion Conference, Hartford, CT	Jul-08	AIAA-2008-4843
870 lbf Reaction Control System Tests using LOx/Ethanol and LOx/Methane at WSTF	Villemarette, Hurlbert, Angstadt, Allred, Mahoney, Peters, Robinson, Veith	JSC	AIAA Joint Propulsion Conference, Hartford, CT	Jul-08	AIAA-2008-5247
Liquid Oxygen / Liquid Methane Testing of the RS-18 Lunar Ascent Engine at Simulated Altitude Conditions at NASA White Sands Test Facility	J.C. Melcher, Jennifer Allred	JSC	55th JANNAF Propulsion Meeting, Boston, MA	May-08	
Development Status of the CECE Cryopgenic Deep Throtting Demonstrator Engine	Giuliano,V. and Kim, T	PWR/MSFC	2nd International Symposium on Propulsion for Space Transportation, Heraklion -Crete, Greece	May-08	
Deep Throttling Common ExtensibleCryogenic Engine (CECE)-Demonstrator 1 Data Mining Task	Leonard, T and Giuliano, V	Pratt&Whitney Rocketdyne	NASA CR	May-08	NASA/CR 2008-215409

Deep Throttling Common ExtensibleCryogenic Engine (CECE)-Demonstrator 1.5 Data Mining Task	Leonard, T and Giuliano, V	Pratt&Whitney Rocketdyne	NASA CR	March-08	NASA/CR 2008-215251
Microwave Igniter - Gaseous Oxygen / Gaseous Methane Vacuum Pressure Tests	Dave Reynolds	MSFC	NASA TM	February-08	NASA/TM 2008-215195
Oxygen-Methane Torch Igniter Design and Testing	Dave Reynolds	MSFC	NASA TM	February-08	NASA/TM 2008-215247
Test Summary Report for Test Program P2514 "6 inch LOX/LCH4 Injector Demonstration"	Sandra Elam, Cynthia Sprader	MSFC	MSFC Internal	September-07	TR ET10-07-01
Liquid Oxygen/Liquid Methane Rocket Engine Development	Dan DeLong, Jeff Greason, and Khaki Rodway McKee	XCOR	SAE 2007 AeroTech Congress and Exhibition, Los Angeles, CA	September-07	
CECE: A Deep Throttling Demonstrator Cryogenic Engine for NASA's Lunar Lander	Giuliani, Leonard, Adamski, Kim	Pratt&Whitney Rocketdyne	AIAA Joint Propulsion Conference, Cincinnati, OH	July-07	AIAA-2007-5480
Design, Fabrication and Test of a LOX/LCH4 RCS Igniter at NASA	Schneider, S. J., John, J. W., and Zoeckler, J. G.	GRC	AIAA Joint Propulsion Conference, Cincinnati, OH	July-07	AIAA-2007-5442 NASA/TM 2007-215038
Oxygen-Methane Torch Igniter Design and Testing	Dave Reynolds	MSFC	MSFC Internal	June-07	
Advanced Technology Development of Cryogenic Liquid Oxygen/Methane Engines Relevant to NASA Constellation Systems	Charles Pierce, Huu Trinh, Jack Chapman, Sandy Elam	MSFC	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
CECE: Technology Development and Demonstration of a Deep Throttling,LOX/LH2 Lunar Lander Propulsion System"	Victor Giuliano (PWR), Timothy Leonard (PWR), Tony Kim (MSFC), Rick Ryan (MSFC)	Pratt&Whitney Rocketdyne	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
Design & Demonstration of a LOX/LCH4 Impinging Injector	Sandra Elam, Christopher Protz, David Reynolds	MSFC	3rd JANNAF Liquid Propulsion Subcommittee Meeting, Denver, Colorado	May-07	
Integrated Performance, Operability and Controls Analysis Enables Successful Deep Throttling of the CECE Demonstrator Engine Toward Lunar Lander Propulsion	Walter Adamski (PWR), Richard, Freese (PWR), Tyler Jennings (PWR)	Pratt&Whitney Rocketdyne	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
Liquid Oxygen/Methane Rocket Engine Development	Robert Engers, Vladimir Balepin, Jeff Greason, and Charles Pierce	ATK-GASL	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
LOX / Methane Microwave Generated Plasma Igniter Testing at NASA's Marshall Space Flight Center	David C. Reynolds, William P. Peschel, and Jack D. Moote	MSFC	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
LOX/LCH4 Ignition Results with Aerojet's RCS LOX/ethanol Igniter	Studak, J. W., Schneider, S. J.	JSC	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
Lunar Lander Propulsion Requirements Derivation and Sensitivity Study Results for the Common Extensible Cryogenic Engine (CECE)	Stephen Mayers (PWR), Russ Joyner (PWR), Josh Hopkins (LM), Tony Bautista (MSFC)	Pratt&Whitney Rocketdyne	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
NGST TR202 Throttling Lunar Descent Pintle Engine	Silvio Chianese, Annik Majamaki, Kathy Gavitt	NGST	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
NGST's TR408, 100 lbf LOX/LCH4 RCE Development Test Results	Kathy Gavitt	NGST	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
Stability Analysis of the Deep Throttling Common Extensible Cryogenic Engine (CECE)	Matthew Long (PWR), Matthew Casiano (MSFC), James Hulka (Sverdrup)	Pratt&Whitney Rocketdyne	54th JANNAF Propulsion Meeting, Denver, Colorado	May-07	
Microwave Igniter - GOX/GCH4 Vacuum Pressure Tests	Dave Reynolds	MSFC	MSFC Internal	March-07	
Microwave Igniter - LOX/GCH4 Ambient Pressure Tests	Dave Reynolds	MSFC	MSFC Internal	February-07	

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Appendix J. National Facilities Listing

Site	Test Stand	Cell Name	Status	Condition	Max Thrust (Klbf)	Max Altitude (Kft)	Propellants available	Tank Pressure LH2 (psi)	Tank Pressure LCH4 (psi)	Tank Pressure LOX (psi)
Aerojet - Sacramento	A Zone	A-2	Active		0.1	180	GN2, IRFNA			
Aerojet - Sacramento	A Zone	A-1	Active		0.1	180	GN2, IRFNA			
Aerojet-Redmond	Chamber 8	Chamber 8	Active	Excellent	0.2	300	MMH, N2H4, N2O4			
NGS - Capistrano	HEPTS A7	HEPTS A7	**Inactive**	Excellent	0.2	150				
NGS - Capistrano	HEPTS A2A	HEPTS A2A	**Inactive**	Excellent	0.2	40	DIH2O, MMH, N2H4, LOX			1200
American Pacific	B-1	B-1	Active		0.3	140	Ghe, GN2, MMH, N2H4, N2O4			
NASA GRCr	RCL-21	RCL-21	Active	Good	0.3	95	Ethanol, GH2, GOX, LCH4, LH2, LOX, RP/JP			
NASA GRCr	RCL-11	RCL-11	Active	Good	0.5	95	Ethanol, GH2, GN2, GOX			
American Pacific	A-2	A-2	Active		0.6	140	Ghe, GN2, MMH, N2H4, N2O4			
Redstone Test Center	Test Stand A	TS-A5	Active	Excellent	1	125	C2H6, N2H4, IRFNA, MON, H2O, N2O4, LCH4, RP-1		2000	
Aerojet-Sacramento	J Zone	J-3	Active		3	190				
AFRL	1-14 E	1-14 E	Active	Excellent	5	125	GH2, GHe, GN2, H2O, N2H4, LH2, LN2	125		
AFRL	1-14 D	1-14 D	Active	Excellent	5	125	GH2, GHe, GN2, H2O, N2H4, N2O4, LN2			
AFRL	1-14 A	1-14 A	Active	Excellent	5	125	DIH2O, GH2, GHe, GN2, GOX, LH2, LN2, LOX	125		35, 1500

Aerojet-Sacramento	J Zone	J-14	**Inactive**		8	180	CLF5, MMH, N2H4, N2O4			
NGS - Capistrano	VETS A1	VETS A1	**Inactive**	Excellent	10.5	45	DIH2O, N2H4, N2O4, RP-1			
NGS-Capistrano	VETS A2	VETS A2	**Inactive**	Excellent	10.5	45	DIH2O, N2H4, N2O4, RP-1			
AFRL	1-42 D	1-42 D	**Mothballed**	Excellent	20	100	GN2, LN2, LOX, Hydraulic Fluid			108, 1200
Aerojet - Sacramento	A Zone	A-8	Active		20	30	GH2, GHe, GN2, GOX, H2O, LH2, LOX	5500		5500
Aerojet-Sacramento	J Zone	J-4	Active		20	120	A50, MMH, N2O4			
AFRL	1-42 A	Pad A	Active	Excellent	50	110	GN2, LN2, LOX			108, 1200
AFRL	1-42 B	1-42 B	Active	Excellent	60	110	GN2, N2H4, LN2, LOX, N2O4,			108, 1200
Aerojet-Sacramento	J Zone	J-5	Active		100	120	GN2, GOX, H2O, MMH, N2O4			

Appendix K. ACS LO2 & Methane Propellant Conditioning System Siting and Quantity Distance Estimates

ACS LOX & Methane Propellant Conditioning System Siting and Quantity Distance Estimates

Introduction

The following analysis demonstrates that the new liquid oxygen (LOX) and liquid methane (LCH4) propellant conditioning systems, to be installed at ACS, can be safely operated with respect to propellant storage quantity distance requirements of the Glenn Safety Manual. This quantity-distance analysis is only applicable to the LOX/Methane thruster testing and the use of the new propellant conditioning systems. It is assumed that no other propellants are on hand during this testing.

This hardware was utilized in RCL Cell 32 for sea-level thruster testing, and is in the process of being moved to ACS to perform altitude thruster testing. This hardware is in support of the PCAD LOX/LCH4 testing program.

Quantity-Distance Background

The DOD standard 6055.9 is the primary reference for determining quantity-distances. The NFPA 55 code also provides separation distance guidelines, covering a wide variety of exposure considerations beyond that covered in the DOD standard. In the DOD standard, quantity-distances are based on the concept that the effects of fire, explosion, and detonation can be reduced to tolerable levels if the source of hazard is kept far enough from personnel and exposures. These distances are based entirely on the estimated damage that could result from an incident, without considering probabilities or frequency of occurrence. Distances are derived from quantities of propellants. The DOD standard does allow for engineering controls that reduce the quantity of propellant involved in an incident and/or limit incidents to only one propellant component and, therefore, reduce estimated worst case exposures. The DOD standard, in particular, provides guidance in the use of barricades and other containment structures to reduce the impact of an explosive event. Ultimately, design judgment and experience is employed to determine the relationship between the effects of an accident and the quantity of material involved in the accident.

For this analysis, the quantity-distance requirements of LOX and LCH4 storage are considered. The DOD standard classifies liquid methane as Group III hazard*, in which case the main hazards are pressure rupture, fragmentation, and gas-phase burning in air. Liquid methane falls under the same category as liquid hydrogen and uses the same quantity-distance charts. The QD charts for liquid hydrogen (liquid methane) are located in the DOD standard (see Table C9.T22) and in the NASA standard NSS 1740.12 (see Table 7.5).

The DOD standard classifies liquid oxygen as Group II hazard*, or strong oxidizer. The QD charts for liquid oxygen are located in the DOD standard** (see Table C9.T20) and in the NASA standard NSS 1740.12 (see Table 7.5).

For quantities of propellant that cannot be credibly prevented from mixing, the TNT equivalent weight is calculated using DOD Table C9.T18 (also available in NSS 1740.12 Table 7.1). Per Table C9.T18, the TNT equivalent weight of a LOX/LCH4 mixture is 10% of the total combined weight of propellant. The quantity-distance of the TNT equivalent mixture is determined using DOD Table C9.T1 or NSS 1740.12 Table 7.6.

With respect to propellant mixing, Section C9.5.5.6.2 of the DOD standard allows the propellant in static test stand run tanks to be excluded from being subject to mixing if the test stand meets all the following criteria:

- All tanks are American Society of Mechanical Engineers (ASME) certified (reference (u)) and maintained per ASME Code, section VIII, Division 1 or Division 2.
- For cryogenic propellants, all tanks are constructed with double wall jacketing.
- Run tankage is protected from fragments produced by an engine malfunction.
- Both the fuel and oxidizer lines contain two (redundant), remotely operated valves to shut off flow in the event of a malfunction.

*Since 2004, the DOD 6055.9 standard no longer uses the "Group I – IV" hazard classification system. However, the NASA standard NSS 1740.12, which follows the 1999 version of the DOD standard, still uses this classification method.
**See 1999 DOD 6055.9 standard. Since 2004, the DOD standard for liquid oxygen is based on the NFPA 55 standard. The NASA NSS 1740.12 standard remains consistent with the 1999 DOD standard.

Analysis Discussion

Table 1 below lists all propellant storage vessels and other exposures applicable in this analysis.

Item #	Vessel	Location	Capacity
1	^LOX Portable Dewar	ACS	92 gal / 876 lbs
2	^LOX Run Tank	ACS	60 gal / 571 lbs
3	^LCH4 Portable Dewar	ACS	85 gal / 300 lbs
4	^LCH4 Run Tank	ACS	60 gal / 212 lbs
5	GHe Tube Trailers	ACS	82500 SCF
6	Liquid Argon Dewar	ACS	2000 gal
7	GN2 Vessels	ACS	Any
8	LN2 Storage	ACS	Any
9	LH2 Run Tank	Cell 31/32	200 gal / 118 lbs
10	RP Run Tank	Cell 31/32	100 gal / 680 lbs
11	LOX Run Tank	Cell 31/32	50 gal / 475 lbs

^indicates new vessels. It is assumed that the facility will have no other propellant storage on hand during use of the propellant conditioning systems.

Table 1: Propellant Storage and Other Exposures

Figure 1 is a plan layout of the ACS test facility, showing the location of the LOX and LCH4 propellant condition systems relative to each other and the test cell. The LOX and LCH4 propellant conditioning systems are positioned to be protected from a test cell failure event, and they are positioned to mitigate the potential of a propagating failure of one system to the other system. As shown, the LOX conditioning system is located outside the west wall of ACS and is, therefore, protected from a catastrophic event in the test cell. The LCH4 propellant conditioning system is located on the south wall of the test cell, also protected from a catastrophic event in the test cell. Lastly, the two propellant condition systems are also out of line-of-sight view of each other; the test cell blocks line-of-sight view between the two propellant conditioning systems. This layout was utilized to satisfy the requirements laid out by Section C9.5.5.6.2 of the DOD standard, which allows the propellant in static test stand run tanks to be excluded from being subject to mixing.

In the event of an engine failure or similar catastrophic event, the maximum uncontrolled propellant mixing considered for the purpose of determining the TNT equivalent explosion potential is (1) the propellant flowing prior to valve isolation and (2) the propellant in the feed lines between the run tank isolation valves and the test stand. Again, as stated above, the run tank quantities are not considered due to engineering controls to prevent potential mixing. The maximum allowable TNT quantity for the test cell is 36 lbs TNT. The estimated maximum credible mixing event is calculated below.

(1) Propellant mixing quantity due to system shutdown response time

Response Time = 0.5 sec
Max LOX Flow = 0.5 lbm/sec
Max LCH4 Flow = 0.25 lbm/sec
Total LOX = 0.25 lbs
Total LCH4 = 0.13 lbs

(2) Propellant in lines subject to mixing in test cell

LOX & LCH4 Line Length = 20 and 18 ft, respectively
LOX & LCH4 Line ID = 0.93 in reducing to 0.40 in
Total LOX = 4.5 lbs
Total LCH4 = 1.5 lbs

The total mixed quantities are then 4.75 lbs and 1.63 lbs of LOX and LCH4 respectively. The TNT equivalence is calculated as follows:

$$TNT\ eq = (4.8+1.6)\times 10\% = 0.6 lbs$$

The resulting mixed quantity is below the allowable 36 lbs for ACS.

The quantity-distance results are shown in Table 2, and Figure 2 shows the quantity-distances relative to the ACS/RCL area.

		LOX Portable Dewar & Run Tank (ACS)	LCH4 Portable Dewar & Run Tank (ACS)	ACS Test Stand
Exposures	Size	1447 lbs	512 lbs	36 lb TNT
LOX Portable Dewar & Run Tank (ACS)	1447 lbs		No separation distance required[1]	No separation distance required[2]
LCH4 Portable Dewar & Run Tank[4] (ACS)	512 lbs	No separation distance required[1]		No separation distance required[2]
ACS Test Stand	36 lb TNT	No separation distance required[2]	No separation distance required[2]	
Cell 32 Test Stand	2.2 lb TNT	No separation distance required[2]	No separation distance required[2]	Operation within existing allowable TNT limits
GHe Tube Trailer (ACS & Cell 32)	82500 SCF	n/a	n/a	No separation distance required[2]
LN2/LAr Dewar (ACS & Cell 32)	Any	n/a	n/a	n/a
GN2 Vessels (ACS)	any	n/a	n/a	n/a
Inhabited building/ public traffic route	Admin buildings/ public roads	124 ft	130 ft	IHBD = 132 ft/ PTRD = 79 ft

[1]Prevention of mixing is assured – propellants are subdivided so that the possibility of accumulative involvement is limited to the quantity of propellant in any one of the divided segments.
[2]Protected by barricade or test cell structure – The term "protected" means that protection from fragments is provided by terrain, effective barricades, nets, or other physical means.

Table 2: Quantity – Distances

Conclusions

The analysis presented demonstrates that the new liquid oxygen (LOX) and liquid methane (LCH4) propellant conditioning systems, installed at ACS, can be safely operated with respect to propellant storage quantity distance requirements of the Glenn Safety Manual. As the design implementation shows, the LOX/LCH4 systems are positioned to prevent a catastrophic accumulative event from occurring. The maximum credible propellant mixing event was calculated and shown to be within allowable limits of the test cell. Lastly, the quantity-distances were determined using DOD and NFPA guidelines and were shown to be safely meet within the RCL area.

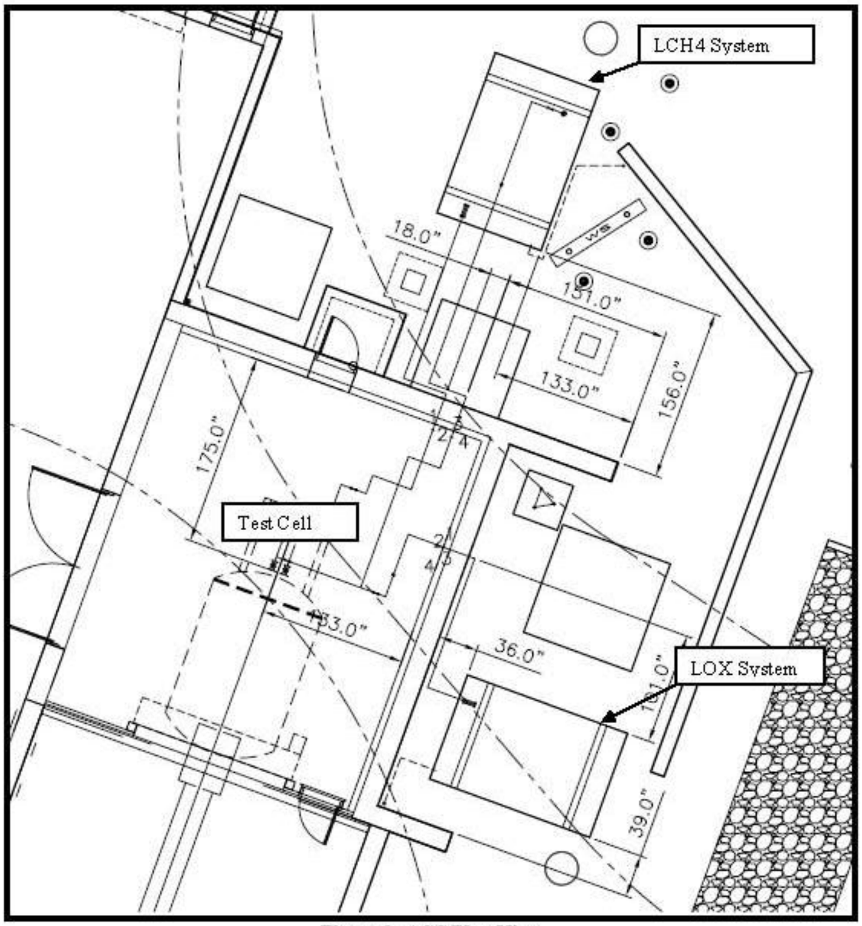

Figure 1: ACS Plan View

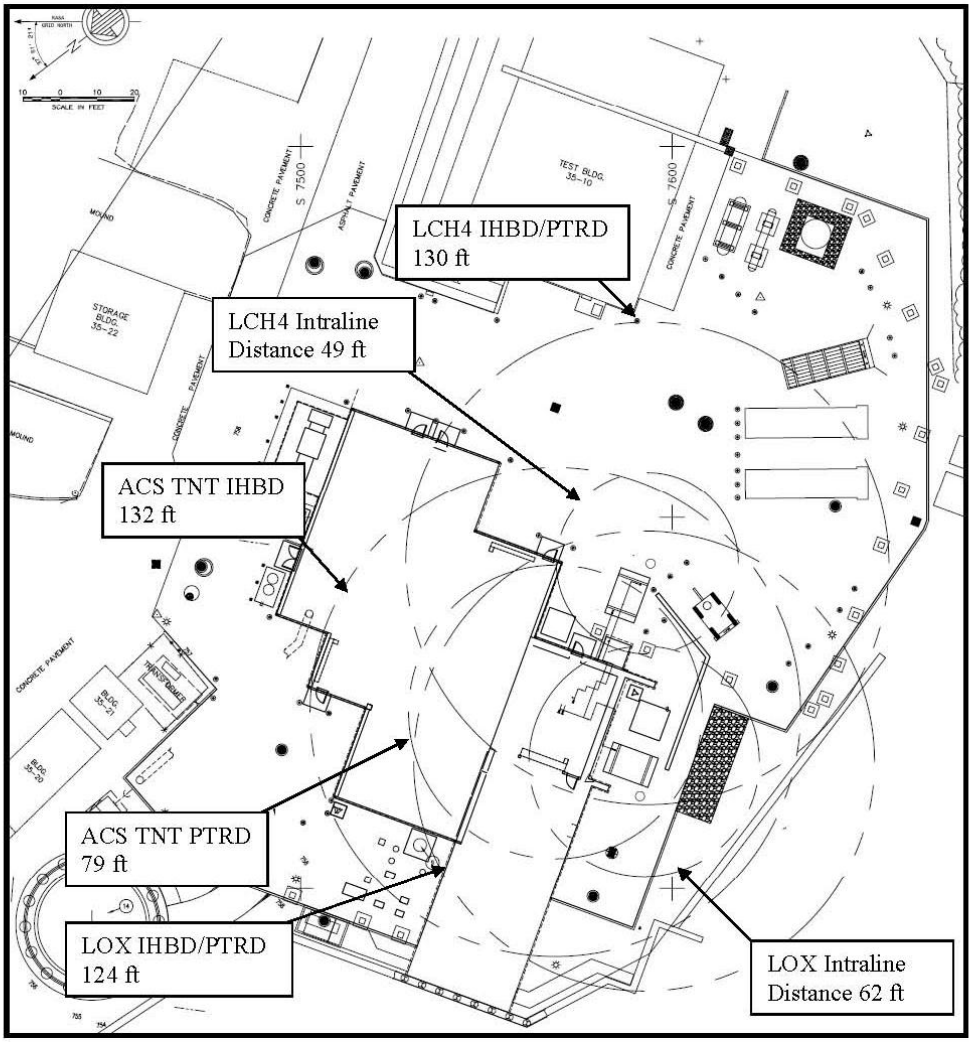

Figure 2: ACS Area QD estimates

Appendix L. Altitude Combustion Stand Independent Review - Independent Cost Assessment

Finding: The PRG Report does not include all the costs to the Agency in the recommendation for demolishing the ACS and RCL32 at GRC and moving the work to WSTF. Costs for demolition and travel of R&T personnel to support testing are not included. The potential cost risks for capital upgrades, test buildup, and testing costs that the Agency may incur due to the relocation are not included or discussed. The basis for estimate is not well documented or supported by data in some areas.

	PRG Recommendation	Additional Costs	Cost Risks	Assessment Comments
Demolition	No cost included	$3-5M		Cost of demolition was not included in PRG. The CoF estimate to demolish both ACS and RCL32 is $3-5M. This would have to be from the Agency Strategic Institutional Investment Finds.
R&T personnel relocated to support testing	No cost included	~$120k/Year		Cost of R&T to support testing was not included in PRG. If R&T personnel remained at GRC these costs would be incurred
Pre Test Build Up	WSTF estimate of $715k (including $165k reserve)		$1.8M (Estimate Delta)	GRC estimate is $2.5M based on historical PCAD costs. Unknown basis for $715k. Not sure tests are fully comparable.
Testing (PCAD)	Cost differences not considered (if any)		~$200k/Month (Estimate Delta)	Based on historical PCAD costs; $146k/Month ACS, $125/Month RCL32, ~$350k/Month (based on PCAD historical at WSTF), Ranged from $300-$380 including a 100 lbf Lox/LCH4 Integrated RCE Test Not sure tests are fully comparable.
Sustainment	$768k through FY15 for ACS $729 through FY15 for RCL32			PRG took GRC O&M costs and escalated them ACS $15k/Year RCL32 $11k/Year

Capital Upgrade -Skid Installation	$800k to dismantle ($100k) and relocate ($20k) ($650k to install) Propellant Conditioning Skid and other items for spares from ACS and RCL32			Unknown basis for $800k. The PRG estimate is for skid dismantle, ship, and installation, there is no propellant conditioning system costs
-Heat Exchanger			Unknown heat exchanger cost (if required)	No heat exchanger cost estimate (if required)
-Sparing/maintenance			Unknown maintenance or sparing cost deltas $100k/Year maintenance increase if MM moves to TS 403 $75k DACs upgrade if AF MM moves to TS 403	The age difference of the facilities have not been taken into consideration. Age and disrepair of LASS systems, along with altitude simulation steam and vacuum system plumbing at WSTF were cited as risks with relatively high likelihood in the "Right Size Study". The ACS is only two years old. MM estimate basis unknown
-New Propellant Conditioning System			-$1.0M Design -$1.8M Build -$3.0M Installation	New Propellant Conditioning System Estimate (by GRC) (Is this required????)

SOMD PPBE 12 Program and Resource Guidance (PRG) Extract (5/7/2010)

WSTF Decision Package:
In the last half of CY 2009, SOMD conducted an assessment of the WSTF core capabilities. The team developed options and plans, to correctly size the WSTF for expected future work. The following six actions were recommended, in order to help preserve the minimum infrastructure and skill sets needed for future operations at WSTF.

3. Close the GRC Altitude Combustion Stand (ACS) and transfer all functions, testing, and related funding to WSTF.
   a. GRC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Thermal Vac Propulsion testing at Altitude Combustion Stand (ACS)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	Notes
GRC Capability O&M	$ -	$ -	$ 184	$ 189	$ 195	$ 201	$ 768	Updated 2/9/2010 - GRC O&M estimate w/ inflation

   b. SOMD / ESMD provide $800k to dismantle and relocate Propellant Conditioning Skid and other items for spares from GRC ACS and RCS 32 to WSTF
   c. GRC to seek Agency Strategic Institutional Investment funds to demolish ACS.

4. Close the GRC RCL Test Stand 32 and transfer all functions, testing, and related funding to WSTF.
   a. GRC to transfer the following budget associated with personnel, operations, and maintenance of the facility to SOMD HSFO for WSTF operations.

Propulsion Testing at RCL Test Stand 32 (ambient testing)								
	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Total	Notes
GRC Capability O&M	$ -	$ 134	$ 142	$ 146	$ 151	$ 155	$ 729	Updated 2/9/2010 - GRC O&M estimate w/ inflation

   b. GRC to seek Agency Strategic Institutional Investment funds to demolish RCL-32.

Basis of Estimates

Demolition

The GRC estimate is based on expert judgment of CoF Branch Chief responsible for relocation of ACS. No data or documentation provided.

Relocation of R&T personnel to support testing

The GRC estimate is based on judgment from previous WSTF test support, considering two people at $3k/person/week for 5 months. No data or documentation provided.

Pre-Test Buildup

The GRC estimate of $2.5M for pre-test buildup at WSTF is based on historical data from previous WSTF facility charges shown in the chart below. No basis for $715k (and reserve) provided

National Aeronautics and Space Administration

Basis of Estimate
Information PCAD Provided to GRC & WSTF Right Sizing Team

Cost Basis
Historical Cost of Doing Work at WSTF 401

Activities	Build-Up	Hot Fire Dates	Total Cost ($K)	Buildup ($K)	In Test Cost per Month ($K)	Source	Description
870-lbf LOx/Ethanol Engine Testing	2001-2006	Jan 2006, Mar 2006	5300	4600	350	NGLT actual	Install LOX, Ethanol, APSTB, and Test 2 months
870-lbf LOx/LCH4 Engine Testing	Sep - Dec 2006	Jan - May 2007	4300	2800	300	PCAD Accounting	Install Methane and test
100-lbf LOx/LCH4 Integrated RCE Test	Aug 2007 - March 2008	Apr - May 2008	4086	2946	380	WSTF email of accounting to PCAD	2 months of testing using SASS
RS18 Methane Engine Testing	Aug 2007 - March 2008	June 2008					3 tests (1-2 sec) using 2 leg LASS, Install thrust stand
Armadillo IPP Methane Engine Testing	Feb - Mar 2009	April 2009	1107	747	360	PCAD Accounting	Test using SASS for 2 weeks (5 tests)

[Source: Basis of Estimate Provided to GRC and WSTF Right Sizing Team, Documented for NESC Team, by PCAD, Aug 2010]

Testing Costs

The GRC estimate of $146k/month for testing at the ACS and $125k/month at RCL32 is based on historical data from previous ACS facility costs of about shown in the chart below. The GRC estimate of $350k/month is based on what WSTF has historically charged PCAD for testing. (These test cost may not be comparable)

National Aeronautics and Space Administration

Basis of Estimate
GRC ACS – PCAD GRC POC Analysis

ACS 100-lbf RCE Test Costs per Typical Month

Item	EP/Mo	Cost/Mo ($k)
Consummables (liquid methane, liquid oxygen, helium, liquid nitrogen, and liquid argon)	N/A	60.00
PCFS operators (2 test engineer WYEs, code FTH)	2	21.67
Lead test operator (WYE, code FTH) main facility	1	10.83
Data system test engineer (WYE, code FTH)	1	10.83
Facility lead electrical test engineer (WYE, code FTH)	1	10.83
Mechanical technician (CS, code FTI)	2	16.67
Electrical technician (CS, code FTI)	1	8.33
Facility test lead engineer (CS, code FTH)	0.5	6.88
Totals for 1 month ACS test:	**8.50**	**146.04**

- Based on ACS tests November 10 through December 4, 2009 (First time test hardware run in facility after relocation, extra test personnel used because of training exercise, later test runs used 6 people and different CS/WYE mix)
- No buildup efforts included

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[Source: Basis of Estimate Provided to GRC and WSTF Right Sizing Team, Documented for NESC Team, by PCAD, Aug 2010]

National Aeronautics and Space Administration

Basis of Estimate GRC Cell 32 – PCAD GRC POC Analysis

RCL Cell 32 100-lbf RCE Test Costs per Typical Month

Item	EP/Mo	Cost/Mo ($k)		EP/Mo	Cost/Mo ($k)
	Past config (with PCFS)			Std test config (no PCFS)	
Consummables (liquid methane, liquid oxygen, helium, liquid nitrogen, and liquid argon)	N/A	56.00		N/A	56.00
PCFS operators (2 test engineer WYEs, code FTH)	2	21.67		0	0.00
Lead test operator (WYE, code FTH) main facility	0.5	5.42		1.5	16.25
Data system test engineer (WYE, code FTH)	0.5	5.42		0.75	8.13
Facility lead electrical test engineer (WYE, code FTH)	0.5	5.42		0.75	8.13
Mechanical technician (CS, code FTI)	2	16.67		1	8.33
Electrical technician (CS, code FTI)	1	8.33		0.5	4.17
Facility test lead engineer (CS, code FTH)	0.5	6.88		0.5	6.88
Totals for 1 month RCL32 testing:	**7.00**	**125.79**		**5.00**	**107.88**

- Based on RCL32 tests May 19 through June 12, 2009 (31 tests in 19 business days with steep learning curve, first time using Propellant Conditioning System, multiple new facility hardware issues, and trouble with methane resupply)
- No buildup efforts included

[Source: Basis of Estimate Provided to GRC and WSTF Right Sizing Team, Documented for NESC Team, by PCAD, Aug 2010]

Sustainment

The GRC estimate is based on judgment from previous facility costs of about $15k/month for ACS and $11k/month for RCL32. No data or documentation provided.

Capital Upgrade Costs

-Propellant Conditioning System transfer to WTSF from GRC

- **Dismantle**
  Cost of $100k is from the WSTF "Right Size" Chart, *Notes* column shown below. No basis of estimate provided or documented.

- **Relocate**
  Cost of $20k is from the WSTF "Right Size" Chart, *Notes* column shown below. No basis of estimate provided or documented

- **Skid Installation**
  Cost of $650k, including 100k of reserve is from the WSTF "Right Size" Chart, *Notes* column shown below. No basis of estimate provided or documented

GRC

Rev 3

Tasks	WSTF Facility Upgrade Required	Upgrade Costs	Risks/Impacts	Notes	Open Items
Thermal Vac Propulsion testing at Altitude Combustion Stand (ACS)	No facility upgrades are anticipated. Test specific build up is required (typical of any new test program).	No facility upgrades required.	Technical risk for achieving propellant temperatures identified in test plan. WSTF has a heat exchanger capable of achieving desired temps, but is yet unproven. Have achieved temps close to requested without heat exchanger. GRC has requested a technical risk be included addressing loss of technical competency at GRC in Space Propulsion R&T due to the consolidation at WSTF. Schedule risks to present test plan due to current test programs in TS401. FY 12 and beyond potential mitigation by moving Air Force Minuteman to TS403. Cost Risk: Cost for test specific build up (typical of any new test program) estimated at $715K (including 165K reserve), based on 100 lbf engine test program currently being performed at ACS. Increase in annual maintenance cost for PCAD estimated at $100K if AF MM program moves to TS403. Increase in DACS upgrade costs estimated at $75K (one time) if AF MM program moves to TS403. GRC has requested that a cost risk associated with researcher travel to WSTF be included to address test support if testing is moved to WSTF.	Costs based on GRC provided test plans for testing currently being done at ACS. Assumes testing done at TS401, after scheduled testing is completed in September. TS401 is used by multiple customers, which allows higher utilization of test teams and facility and allows sharing of some costs. Verified and updated delta DACS costs to PCAD if MM moved to TS403. Costs for LOX/LCH4 skid transfer to WSTF have been estimated: Disassembly at GRC 100K; Ship to WSTF 20K; Installation of both skids into WSTF test system 650K (including 100K reserve)	Discussions with GRC 1/20 identified the following concerns: 1) Capability of Hx to meet desired temperature range. 2) Schedule issues with PCAD and MM testing at TS401

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[Source: White Sands Test Facility "Right Size", WSTF PRG Guidance and Center Feedback, Jan 29, 2010]

- Heat Exchanger

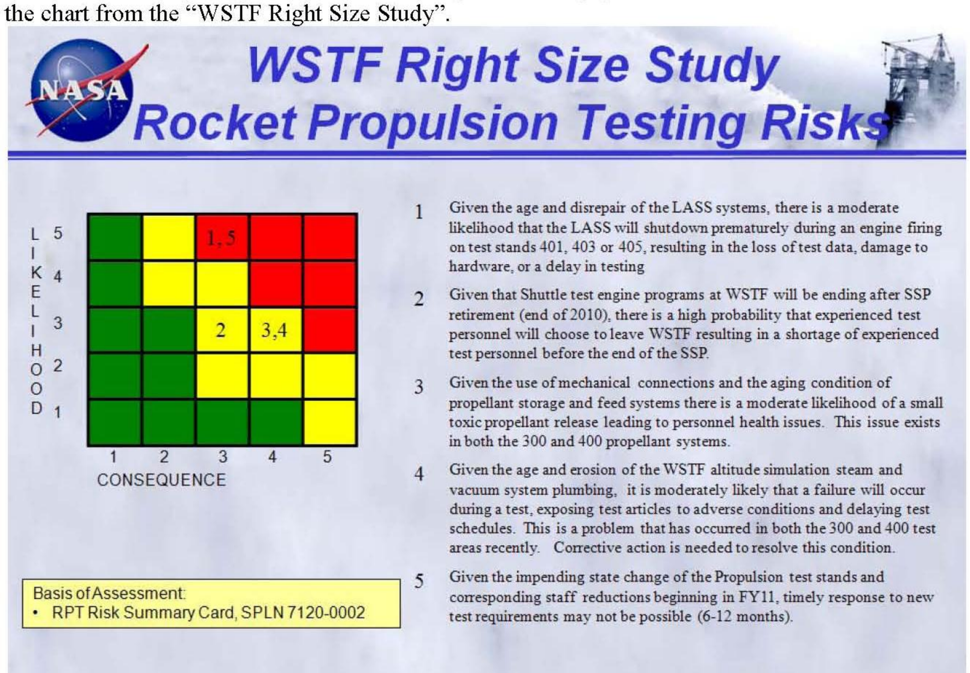
Unknown requirement or cost estimate for modification or procurement upgrade if any for heat exchanger noted as a technical risk in the WSTF "Right Size" Chart on previous page.

-Sparing/Repair

Cost risk for additional maintenance of $100k/Year for PCAD if AF MM Program moves to TS 403 is noted in WSTF "Right Size" Study Chart shown on previous page. No basis of estimate provided or documented. It is unknown whether similar maintenance charges would apply to other type testing without known requirements.

Cost risk for DACS upgrade of $75k for PCAD if AF MM Program moves to TS 403 is noted in WSTF "Right Size" Study Chart shown on previous page. No basis of estimate provided or documented. It is unknown whether similar maintenance charges would apply to other type testing without known requirements.

No estimates for sparing for repair have been provided only qualitative assessments as shown in the chart from the "WSTF Right Size Study".



[Source: White Sands Test Facility "Right Size", Phase 1, Sep 3, 2009]

-Propellant Conditioning System Estimate by GRC

Source:
Bruce Rosenthal
NASA Glenn Research Center
Altitude Combustion Stand
Facility Manager
216-433-5027

Cost to Design, Build and Install Liquid Methane and Liquid Oxygen Propellant Conditioning Systems (PCS) at NASA Glenn ACS Facility

Cost is broken down into three phases 1) design, 2) build and 3) install. The period during which each phase occurred is given. A majority of the cost was a result of funding to aerospace prime contractor Sierra Lobo, Inc. (SLI). For each category the costs are separated into a) Sierra Lobo, Inc. prime contract, b) in-house labor (includes both WYE's and FTE's), and c) procurements (other than prime contract). Total cost comes to $ 5.8 M.

1) Design - $1.0 M : Apr. 2007 to Apr. 2008
   a) SLI prime contract - $878 K
   b) In house labor - $150 K
   c) Procurements - n/a (not applicable)

2) Build - $1.8 M : Apr. 2008 to Sept. 2008
   a) SLI prime contract - $1.8 M
   b) In house labor – minimal
   c) Procurements - n/a

3) Installation at ACS * (see note below) - $3.0 M : July 2008 to Oct. 2009
   a) SLI prime contract - $128 K
   b) In house labor – $1.9 M
   c) Procurements – $1.0 M

*Does not include cost of installation for checkout testing at GRC RCL 32 facility.

Some major aspects of Propellant Condition Feed System's installation costs included placement and mounting of the PCS's, utility hookups , propellant line extensions into the test cell, establishment of propellant transfer stations, thermal insulation, vent stack installation and hookups, control interfaces, and establishment of liquid nitrogen and liquid argon supply lines.

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Other data on WSTF PCAD performance

PCAD Cost Evaluation for RS-18 and 100-lbf Test Projects

Period of Performance

Planned: May, 2007 through June 2008
Actual: May 2007 through August 2008

Overall Cost Comparison

	Estimated Cost ($M)	Actual Cost ($M)	Delta Cost ($M)	Error (%)
Contractor Cost	2.722	3.246	0.524	16.143
Materials	0.499	0.756	0.257	33.995
Labor+taxes+award fee	2.263	2.490	0.227	9.116
Hours	*35,332*	*34,996*	*-336*	*-0.960*
NASA Procurements	0	0.200	0.200	100.000
GSP	0.537	0.640	0.103	16.094
TOTAL	**3.259**	**4.086**	**0.827**	**20.240**

Contractor materials were underestimated by 33%. Several upgrades were approved at TS 401 that had not been a part of the original estimate, including new dome cameras at the test stand ($30K), new video monitors in the control center ($40K), borescope for injector inspection ($36K), portable helium mass spectrometer for leak checks ($31K), and miscellaneous electrical equipment ($10K). In retrospect, a more formalized agreement could have been made when these upgrades were negotiated and agreed upon. A revision should have been made to the original estimate at that time.

In addition, altitude costs (blanket PRs under the contract) were higher than anticipated during 100-lbf testing (SASS). Diesel costs during 100-lbf testing were estimated at $40K, assuming 40 hours of run time. The actual SASS run time was 80 hours and exceeded the estimated cost by $40K.

Contractor labor costs were underestimated by 9%. In comparing the estimated versus actual hours spent by contractors on the project, the overall difference is negligible (336 hrs). However the rate used to estimate the labor cost was off by approximately $7/hr. On future projects, an updated average labor rate will be utilized and will range between $75 and $80 per hour per contractor.

NASA Procurements were significantly underestimated. WSTF established a contract with DESC/Lackland Air Force Base for delivery of Grade B Methane in mid FY07. To assist other PCAD-supported test facilities with obtaining methane, a contract modification was negotiated for delivery to Northrop Grumman, Aerojet Sacramento, and Armadillo Aerospace. WSTF had planned to order no more than 6 loads of LCH4 to support RS-18 and 100-lbf testing, but failed to include this in the original estimate to PCAD. The total cost of methane between the 4 test facilities totaled $200K. Roughly $40K of that was offloads at WSTF. For better planning on future projects, WSTF will request that DESC provide the projected propellant usage for all facilities that use the WSTF Methane contract.

General Service Pool is the fee charged to projects to maintain WSTF facilities. The amount of fee removed is approximated at 30% on contractor costs. The increase in GSP is a direct result of the over expenditure on contractor dollars. By using the updated average labor rate to estimate future projects, the GSP estimate will improve.

Appendix M. Stakeholder Outbrief Presentation – To Add